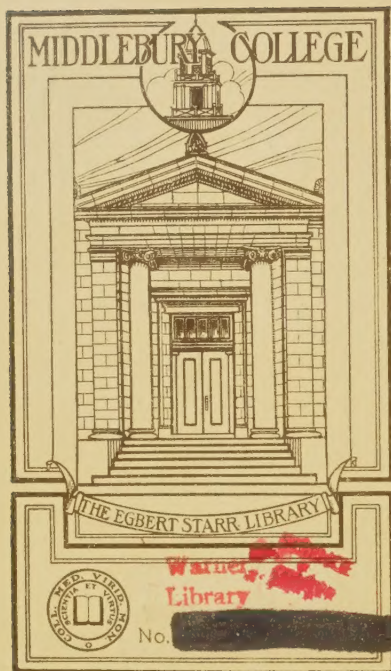








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EDMUND W. SINNOTT, CONSULTING EDITOR

A TEXTBOOK OF SYSTEMATIC BOTANY

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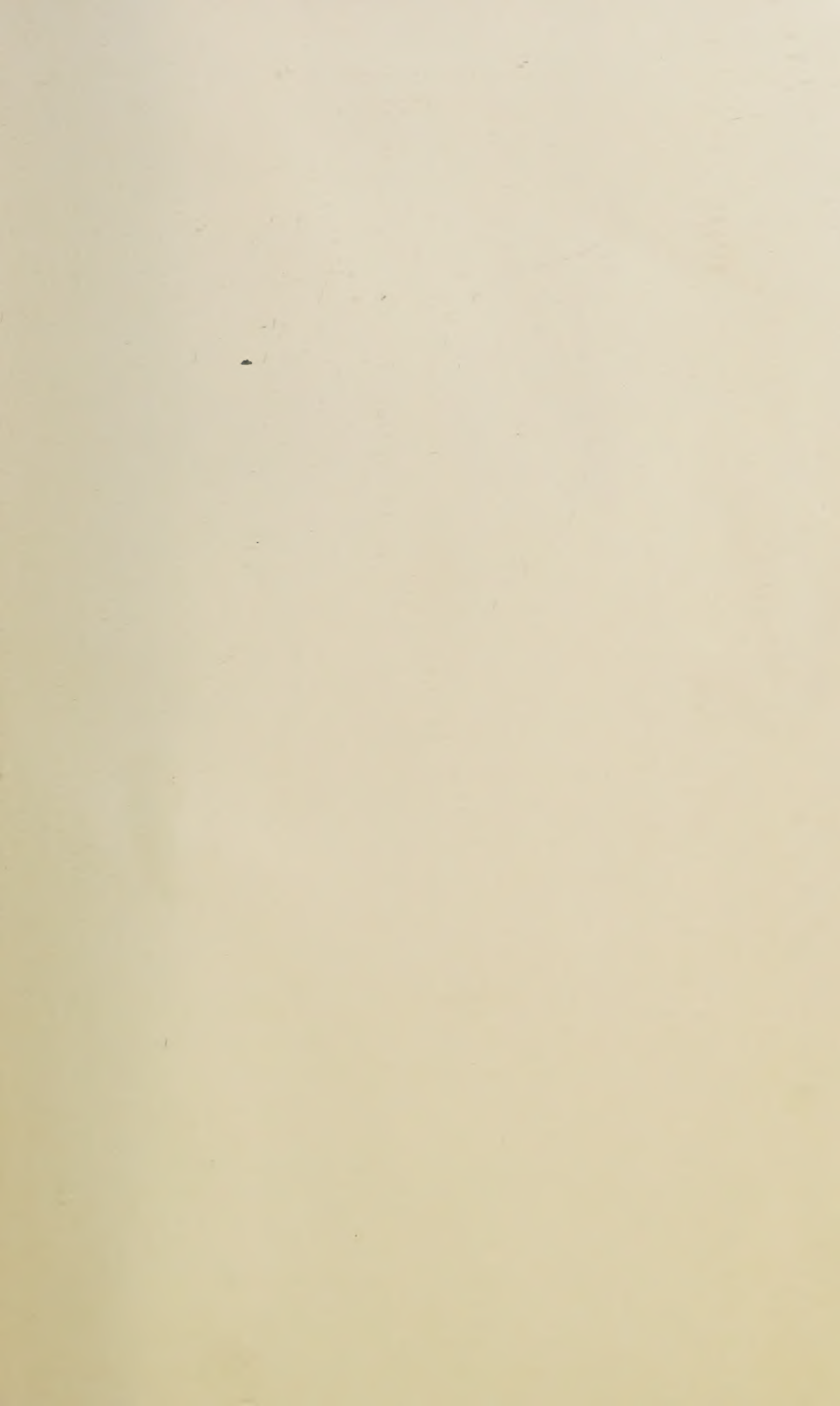
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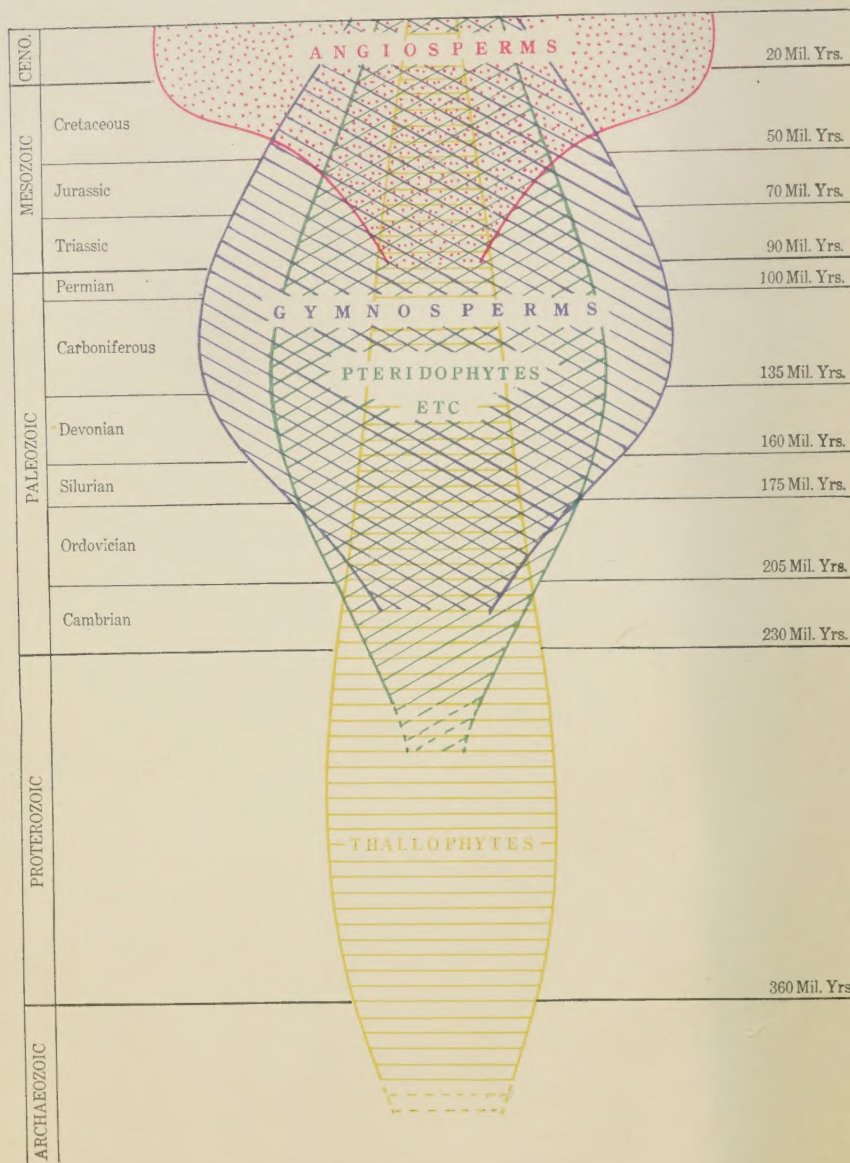
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DEVELOPMENT OF PLANT LIFE



FRONTISPIECE.—Successions of plants, showing the estimated time of origin of the different groups and the relative prevalence at different periods. (Modified after Berry)

A TEXTBOOK OF SYSTEMATIC BOTANY

BY

DEANE B. SWINGLE

Professor of Botany, Montana State College

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.

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TO
MY WIFE

Who has been more to
this book than co-author

PREFACE

It is a matter of more than passing interest that in the oldest branch of botany comparatively little attention has been given to methods of presentation to the student. While the teaching of most botanical subjects in our colleges is on a par with that of other branches of learning, the teaching of taxonomy, especially that of the higher plants, is not always a credit to the profession. Too often highly trained specialists, with a vital interest in their collections and an intense zeal for precise distinctions and accurate determinations, are content to lead their students through the paths of the apprentice, with little regard for anything but the technique of collecting, preserving, and naming, and certainly with little attempt to unfold to them in logical sequence the underlying principles of this branch of botanical science. Of late, a few teachers are giving lectures on the principles fundamental to systematic botany, but lectures not supplemented by assigned reading are wholly inadequate for the beginner. In the field of general botany we have a wealth of textbooks, some of them splendidly written; and in plant physiology, histology, ecology, and even in the newer fields of cytology and phytopathology a few good texts can be found. But while the naming and classifying of plants has been going on for centuries, no textbook is available that adequately sets forth the principles of taxonomy and nomenclature.¹

A number of good reference books there are, to be sure, and many valuable papers on most phases of the subject. International congresses have been held to encourage uniformity in principle and practice. We have good systematists, and others

¹ The author has not overlooked two books of especial value in this connection. The first is J. C. Willis' "Flowering Plants and Ferns" which contains some valuable information on principles and methods. The second is A. S. Hitchcock's "Descriptive Systematic Botany" published in 1925. Professor Hitchcock's book is especially valuable in its up-to-date treatment and its well-chosen topics fundamental to modern taxonomy and nomenclature. From the preface and the method of treatment, however, it is evidently intended as a reference book rather than a classroom text.

are being reared to take their places. Notwithstanding these facts, however, no textbook is available to bring systematic botany to the student in logical and pedagogical form. It is for this reason only that these pages are written.

This book is an outgrowth of a course given at the Montana State College for the last fifteen years. It is designed to cover one semester, preferably the second, so that the fundamentals may be established during the colder months, and supplemented by field work with the opening of spring. Systematic botany should be preceded by a course in general botany, without which the student will fail to grasp the fundamental principles of phylogenetic taxonomy and will find that the examples used are mostly unfamiliar and meaningless.

It is not intended that this text shall in any way supplant the manuals used for identifying plants. These are already numerous and cover the flora of practically every part of the country, though lacking somewhat in harmony of detail, and this book is to supplement rather than to compete with them.

The purpose of the first part is to set forth and illustrate the principles and rules on which systematic botany is based. The second part describes some sixty families of spermatophytes, chosen because of their size, economic importance, or peculiar interest. To secure best results, a considerable portion of the time must be given to laboratory and field work, chiefly devoted to actual identification of the local flora by the use of the keys and manuals best suited to that locality.

The author takes this opportunity of expressing his gratitude to all who have aided in the work, either through valuable suggestions or the use of their libraries, and especially to R. A. Harper of Columbia University, J. E. Kirkwood of Montana State University, Ernst A. Bessey and H. T. Darlington of the Michigan Agricultural College, A. S. Hitchcock of the U. S. Department of Agriculture, M. L. Fernald of Harvard University, Aven Nelson of the University of Wyoming, Alfred Gundersen of the Brooklyn Botanic Garden, and J. R. Pool and T. J. Fitzpatrick of the University of Nebraska.

DEANE B. SWINGLE.

BOZEMAN, MONTANA.

February, 1928.

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A TEXTBOOK OF SYSTEMATIC BOTANY

INTRODUCTION

Modern systematic botany holds a unique position. It is a science in itself with its own laws and principles, and its own ideals. The orderly arrangement of the wealth of vegetation that adorns the earth, a terminology understood by all nations, an application of the laws of evolution—these things in themselves are worthy of man's best efforts. It has, however, another service to perform. It must aid those in other fields of endeavor, who make use of plants for many purposes, to know the identity of the kinds they use and their relationships to others.

Nomenclature deals with names, which may or may not indicate relationships. Taxonomy seeks to group plants on a basis of similarities and differences, these being, as we now believe, expressions of actual phylogenetic relationships—"blood relationships" as we say of the higher animals. We might conceivably have names without classification, but we can scarcely have classification without names. Indeed, names are necessary in almost any kind of discussion.

Particularly close is the relationship between systematic botany and ecology. Names have little interest in themselves. It is only when attached to objects of study that names become significant. The out-of-door botanist not only names the plants but inevitably notes their distribution, environment, and seasonal development.

In America the development of botany in all its aspects has been an interesting one. The great pioneer botanist, Asa Gray, found here a veritable paradise, a vast and little-explored region with many familiar forms and not a few that were new to science. His tireless efforts, boundless enthusiasm, keen discrimination, and sympathetic attitude endeared him to his students and associates. It is little wonder that his modest laboratories

became a Mecca for American botanists, both professional and amateur.

His influence was far-reaching, especially as it came during a period when many were becoming interested in pioneer work on the flora of this new country. In colleges and universities the taxonomic aspect of botany became almost an obsession. The making of herbaria dominated botanical departments. Dr. Gray had sought to present at Harvard University a well-balanced course in botany, including morphology and physiology, but the general enthusiasm ran irresistibly into the taxonomic field. As a result many in the next generation of botanists used and taught this branch almost to the exclusion of others. This was quite unfortunate, for the impression was given that the chief purpose of botany was to collect and name plants. Such an objective alone could hardly meet the approval of the masses, and botany lost favor accordingly. Appropriations were grudgingly given, and many students resented the courses where the practical value was not obvious. The strenuous efforts of C. E. Bessey, W. A. Kellerman, W. G. Farlow, John M. Coulter, and others soon restored the balance of emphasis in the colleges, and, indeed, the pendulum again swung too far. Many of the herbaria were stored away, classification ceased to be taught, and hundreds of students graduated from botanical courses without knowing the names of even a score of plants, and without ever having attempted to use an analytical key. The layman, however, moving more slowly, continued to believe that botany had its beginning and end in nomenclature.

At last systematic botany in this country has found its proper place with the other branches of botanical science. It has its highly trained specialists, the botanical student includes it in his curriculum, and the amateur finds in it his chief source of delight.

Under these circumstances the antiquated methods of teaching systematic botany can well be replaced by the more modern ones that have made botanical science as a whole a subject of respect.

PART I
PRINCIPLES AND METHODS

CHAPTER I

PURPOSES OF SYSTEMATIC BOTANY

Through many centuries systematic botany has had such a checkered career that its true perspective has often been lost from sight. Like many other subjects it has several objectives. The scientific mind is not content with names alone. If we study any group of objects, from atoms to heavenly bodies, we inevitably endeavor to classify the members of the group. This orderly arrangement is the first step in scientific treatment.

The systematic botanist finds about him millions of individual plants. No two are exactly alike, yet some are nearly so, while others are so different that they show scarcely any bond of relationship. By noting and comparing the similarities and differences, the followers of this science have brought out of chaos a fairly orderly system. Thus a profession has been set up in which the specialist performs a service to all who deal with plants, by determining the names, as known internationally, of thousands of specimens. He ascertains their group relationships, their distribution, properties, and other points of interest. Systematic botany makes a groundwork for all sciences dealing with plants.

The myriad uses of plants make it necessary for many who are not taxonomic specialists to have some knowledge of their names and classifications. When we consider that green plants offer the greatest means of utilizing energy from the sun, that plants directly or indirectly furnish most of our food, clothing, shelter, fuel, medicine, paper, decorative materials, and many other useful things, we are made to realize that an orderly classification of them, understood in some measure by all civilized people, does much to prevent confusion and to facilitate cooperative effort.

An important difference between a person who treats a subject from a scientific viewpoint, and one who makes use of a smattering knowledge of the same subject, is that the former must classify as well as name, while the latter is content with isolated names alone, and only the ones he uses. As an illustration, professional bacteriologists are struggling desperately for an adequate system

of classification, but the majority of practicing physicians prefer to apply the name "bacillus" with varying adjectives to most disease-producing bacteria, and to ignore the other species.

There is another field for the systematist that must not be overlooked. Someone must apply to the plant kingdom as a whole the findings of the paleobotanist and the geneticist. It is admitted by all that the best system of classification we now have is far from perfect. In many groups of plants, perhaps in most, the classification has proceeded only far enough to connect loosely certain forms that have a kind of resemblance which may or may not represent actual relationship.

The work of the paleobotanist is slowly bringing to light evidences that have a real bearing on taxonomy, especially that of plants having alternation of generations. The practical plant breeders and geneticists, especially those of recent years, have also brought to light, by actual experiment, a wealth of information concerning the relationships of the higher plants. The systematic botanist has not yet reached the point where he can afford to be static. His classification must be flexible and frequently revised to embody the newer information, and to adjust itself to the newer viewpoints. If he takes this progressive attitude, he can be of tremendous service in summarizing and utilizing the discoveries of investigators in related fields. He has a duty beyond the mere naming of plants.

More and more the spirit of service is pervading the scientific world. With increasing effectiveness representative men in each science will apply their work and that of their colleagues to everyday life. In harmony with this tendency, the systematic botanist of tomorrow will add to the names and classification of plants much information of value to the human race.

CHAPTER II

EVOLUTION IN RELATION TO TAXONOMY

Many bases of classification have come into use, each designed to serve a special purpose. Some of these grew out of the economic uses of plants; others were founded on gross structural resemblances as habit of growth—trees, shrubs, vines and herbs. All such systems were fragmentary and incomplete, because those plants that did not fit the classification had a different interest and were ignored. For example, non-medicinal plants received little consideration by the early herbalists. Only one system of classification has made any pretense to completeness, and that is the one now in use which is based on natural relationships.

Ideals in Classification.—The ideal classification must embody two qualities. It must show actual genetic relationships and it must be reasonably convenient for practical use. If it fails to show true relationship it is spoken of as “artificial,” and does not satisfy the discriminating thinker. Too often, however, as in the bacteria and some groups of fungi and algae, it has had to suffice until a better plan could be devised. If, on the other hand, a system is too involved and difficult of comprehension, and especially if, in addition to these faults, the phylogenetic evidences are incomplete and debatable, such a system fails to gain general acceptance, and may even have to give way to one that is more artificial. Most botanists believe that different groups of fungi originated from more or less distantly related groups of algae, and that a phylogenetic classification should show a closer relationship between certain fungi and certain algae than between different fungi. Nevertheless they continue to treat the fungi as if they were a homogeneous unit.

One of the advantages of a phylogenetic classification over an artificial one is that it is safer to generalize in related groups than in unrelated ones. If, for example, one is well informed concerning a few species of Pinaceae, Gramineae, Leguminosae, or Cucurbitaceae, he can assume the likelihood that some of his knowledge will apply to other members of the same family, although, of

course, some verification will be necessary. On the other hand, if all plants with compound leaves were considered to be a family, no generalization would be safe except one regarding the leaves. Fortunately, in most of the spermatophytes phylogeny and convenience can be fairly well combined.

Evolution as a Basis for Classification.—The ideals of classification just stated presuppose the origin of species by evolution. The student is therefore given three alternatives: to reject one of these ideals summarily, to accept it blindly on faith in his instructor, or to look into the proofs. The last named is the scientific method.

EVIDENCES OF EVOLUTION

At the outset the meaning of organic evolution should be made clear. Evolution is believed to have produced all existing forms of life from more ancient forms that were fewer in number and simpler in structure than those of the present day. It is not held that one group existing today came from another group existing today, but that two similar groups had a common ancestor more or less like both, but usually resembling the lower more closely than the higher.

A great deal has been written in recent years on the evidences of evolution, and also on the methods of its operation, concerning which some half-dozen plausible theories have been proposed. Space limits us here, however, to a brief outline of the best accepted evidence on which the belief in evolution is based.

Geological Evidence.—It is an established fact that the surface of the earth is changing and has been doing so for ages. Land has been lifted out of the sea and mountains have been worn away to make successive layers of earth in the valleys, these in turn being lifted in some cases. In these successive strata many fossils are found, the remains of prehistoric plants and animals. Had all life been created during a single century and not altered by evolution thereafter, fossils of present-day plants and animals, both higher and lower, would occur together in some of these strata, probably in parts of all but the oldest. Such, however, is not the case. The older strata, those of the pre-Cambrian eras (see frontispiece and table on p. 9), give evidence of only low forms of life, marine algae, invertebrate animals, etc., mostly too soft in texture to leave clear-cut fossils, but forming deposits of graphite and calcium carbonate. Strata not quite so old, those

UPPER HALF OF PALEONTOLOGICAL RECORD¹

Psychozoic era: dominance of man and herbaceous plants	Recent or post-glacial time, 25,000 yrs.	Receding of polar ice caps, moderate rise of temperature, temperature zonation, aridity of intermountain regions. Wane of forest trees, dominance of herbaceous plants and of civilized man	
Cenozoic era: dominance of mammals and angiosperms	Late cenozoic (Neogenic) period	Pleistocene or glacial epoch	Ice caps and glacial conditions extending from poles into temperate zones. Extinction of many large mammals and trees. Survival of hardy adaptable types, especially herbaceous plants. Elevation and extension of continents. Beginnings of civilization
		1,000,000 yrs. Pliocene epoch	Moderate cooling of climate with increasing aridity. More restriction of forests. Appearance of man. Elevation of the Andes
		Miocene epoch	Slight cooling of climate with aridity in places. Slight decrease of forest areas. Increase of grasses and culmination of mammals. Elevation of the Swiss Alps
	10,000,000 yrs.	Oligocene epoch	Warm, moist climate. Zenith of forest areas. Increase of higher mammals and of birds. Appearance of primates. Elevation of the Pyrenees.
	Early cenozoic (Paleogene) period		Climate cool and semi-arid, then warm and humid. Extension of forests into polar regions. Wane of archaic mammals. Appearance of birds and marine mammals. Continued elevation of the Rockies
	20,000,000 yrs.	Eocene epoch	Fluctuating climate. Increase in modern forests, including birch, walnut, and maple. Extinction of dinosaurs. Increase of mammals. Extensive coal deposits from gymnosperms and some pteridophytes. Elevation of the Rockies
Mesozoic era: dominance of reptiles and gymnosperms	Upper cretaceous period	Tropical climate, depression of land with invasion of seas continuing into Upper cretaceous. Earliest known palms and grasses. Beginnings of modern forests including poplars and sassafras. Zenith of dinosaurs	
	Lower cretaceous period	Gradually rising temperature; colder at poles. Widespread warm seas. Increase of dicotyledons. Numerous toothed birds and flying reptiles. Dinosaurs predominant. Beginning of the Sierra Nevada	
	50,000,000 yrs.	Warm, semi-arid climate. Shallow warm seas and lagoons. Gymnosperms and pteridophytes continuing to wane but still dominant. Probable origin of dicotyledons. Rise of dinosaurs. Appearance of mammals. Igneous activity, mountain making, and land extension	
	Jurassic period	Dry, glacial climate especially in southern hemisphere. Gymnosperms beginning to wane but still dominant. Great mortality of specialized animals and plants. Land vertebrates increasing. Extensive salt deposits	
	70,000,000 yrs.	Climate warm and humid. Pteridophytes beginning to wane, gymnosperms reaching zenith. Increase of reptiles and insects. Amphibians abundant. Extensive coal deposits from pteridophytes and gymnosperms	
	Triassic period	Land climate temperate, seas cool. Winter climate in mountains. Zenith of pteridophytes, gymnosperms approaching zenith. Sharks and crinoids abundant. Amphibians increasing. Thin coal deposits	
Paleozoic era: dominance of fishes and pteridophytes	90,000,000 yrs.	Warm climate with moderately dry air. Rapid increase of pteridophytes and gymnosperms. Appearance of amphibians and cephalopods. Fishes predominant	
	Permian period	Warm climate, semi-arid in certain regions. Probable increase of pteridophytes and gymnosperms. Appearance of scorpions, myriapods, and lung-fishes (first air-breathing animals)	
	100,000,000 yrs.	Continued warm climate. Possible origin of gymnosperms and increase of pteridophytes, but marine algae still dominating. Corals, bryozoans, and brachiopods abundant. Appearance of armored fishes	
	Pennsylvanian (Upper carboniferous) period	Warm uniform climate over the earth. Possible origin of pteridophytes. Marine algae dominating. First known marine animals (trilobites and brachiopods)	
	115,000,000 yrs.		
	Mississippian (Lower carboniferous) period		
Paleozoic era: dominance of fishes and pteridophytes	135,000,000 yrs.		
	Devonian period		
	160,000,000 yrs.		
	Silurian period		
	175,000,000 yrs.		
	Champlanian (Ordovician) period		
Paleozoic era: dominance of fishes and pteridophytes	205,000,000 yrs.		
	Cambrian period		
Paleozoic era: dominance of fishes and pteridophytes	230,000,000 yrs.		

¹ The data recorded in this table are derived from the character of the earth's strata and the fossils which they contain. In some cases the oldest known fossils are of such specialized forms as to leave no doubt that they had a long line of ancestry in the same phylum, hence the probable origin of that group is indicated at an earlier period. The figures given are estimates of the time from the dawn of each period to the present. As the fossil records are fragmentary, the table must be looked upon as expressing prevailing opinion, and subject to some revision.

of the Paleozoic era, bear fossils of complex invertebrates, lower vertebrates, seaweeds, Pteridophytes, and Gymnosperms. Not before the Mesozoic era were fossils of mammals and angiosperms produced, while the apes and man left no fossils below the younger layers of the Cenozoic era. That this entire span of life development covered millions of years is generally accepted.

Anatomical Evidence.—Strikingly fundamental similarities occur in groups of plants and animals that show great variety in structural details. In the spermatophytes every part of the sporophyte is some form of root, stem, or leaf, and every plant has all three of these structures though they differ greatly in form and function. In all the vertebrates, excepting the most primitive, there are four limbs, sometimes in a rudimentary condition, and the skeleton of the arm and forefoot, for example, compares almost bone for bone with that in such superficially different structures as the walking organs of the bear, the swimming flippers of the whale, the wings of the bat, and the grasping organs of man. Surely direct creation would have found a simpler method of construction, in some cases more naturally suited to the purpose. Evolutionary development, however, would be likely to modify existing structures rather than to create new ones.

Embryological Evidence.—The ancients believed that, in general, living things started with an appearance much like miniature adults, growth and development being merely processes of enlargement of each individual organ. Scientific observation has revealed that such is not usually the case. The fern, beginning with the germinating spore, first resembles a green alga. From this develops a small thallus like those of the liverworts. This prothallium in turn is replaced by the leafy mature form with which all are familiar.

The frog in its metamorphosis goes from a one-celled state through the tadpole stage, more like fish than amphibian, and changes to adult form by loss of tail and gills and development of legs and lungs.

Insect larvae have no wings, not even rudimentary ones, and resemble worms, which they are often called. But these larvae, by losing certain leg-like structures, taking on permanent legs and wings, and developing a definite segmentation, become in adult life strikingly different creatures.

Ontogeny is a term used to express such a series of embryonic stages of the individual as those just described. *Phylogeny*, on the

other hand, expresses the evolutionary history of a race of beings. Von Baer's law of recapitulation, translated into English, states that "ontogeny is a brief repetition of phylogeny." This law has been highly useful in tracing relationships in animals and plants.

Vestigial Structures.—In a close examination of the higher plants and animals one finds many structures wholly useless and sometimes actually detrimental to the individual. Of what use to plants are the scale-like leaves on rhizomes and tubers, stamens without anthers, and antheridial cells of germinating pollen grains? Why should the legs of the horse include so many little bones, some of which by pressure against others become inflamed and cause splints and spavins? Why the easily infected vermiform appendix, or the scattering body hairs of the human being? Why so many useless structures in higher forms of life and so few in lower forms? As a result of direct creation such structures would seem absurd.

Evolutionary development, however, would almost inevitably be accompanied by such vestiges of once useful organs. Great and varied environmental changes have taken place on the earth during the eras of its inhabitation. The new environmental conditions profoundly affected the existing plants and animals. Some species unable to adjust themselves were exterminated, and but for their fossil remains we would never know that they had existed. Other species became adapted to the new conditions by structural modification. Some organs, such as bones, for example, were lengthened, shortened, or otherwise modified, and in some cases were entirely lost. Useless structures became encumbrances and the species best fitted to survive were those in which these superfluous parts were rapidly reduced and made unobtrusive. It sometimes happened, however, that another change of environment reestablished a need for the organ in its original or equivalent form. If it was too far gone or too greatly modified, the victim perished, as doubtless happened in numerous instances, for by the law of irreversible evolution (see p. 16) animals and plants do not ordinarily go back to earlier states. Had the bodies of living things been so unstable that organs would quickly and entirely disappear with a brief change in the weather or food supply, organic adaptation would have been oversensitive and caused destruction rather than protection. That myriad forms of life did survive profound environmental changes

is evidence of the tenacity with which unused organs persisted. Modification rather than destruction of organs appears to have been the fortunate rule. Furthermore, by this hypothesis vestigial structures would be more frequent in the versatile, highly complex spermatophytes and vertebrates, and more rare in the simple conservative lower forms.

Thus it can be seen that by a theory of evolution these vestigial or rudimentary structures can be naturally explained, while by a theory of direct creation they are inexplicable and inharmonious.

Recent Productions.—It must not be supposed that evolution has come to a standstill. Remarkable changes in plants and animals have taken place within the history of civilized man. Varieties of corn, fruits, and vegetables, wonderful flowers, breeds of dogs, pigeons, and goldfish—all these and many more testify to the fact that existing forms of life have actually come from ancestry that was very different. That we now call these different cultivated and domestic forms varieties rather than species is of little significance, for there is no doubt that many of them, if found wild, would unhesitatingly be given different specific names.

Furthermore, without special manipulation by the plant breeder, new forms have been observed to come into being, in some cases from wild plants. The mutation theory of de Vries assumes that most evolutionary change takes place in this way.

The fact must not be overlooked that these recent productions have been made in a relatively brief time. Compared with the duration of life on the earth, the existence of civilized man has been as a fraction of a second is to a century. One could not expect, therefore, that a considerable number of new species would become established in so brief a span.

ACCEPTANCE OF THE DOCTRINE OF EVOLUTION

That the doctrine of evolution when first set forth in something like its present form by Darwin and his associates caused much discord throughout the Christian world is a matter of history. Since Darwin's time the evidence for it has been greatly strengthened, and it is also becoming clear that evolution is not in conflict with any essential religious belief. Indeed, in the minds of many people the conception of the Creator is amplified and beautified by this newer outlook on the method of organic creation.

In all branches of natural science the doctrine of evolution is universally accepted. It has revolutionized the classification of plants and animals, and what is most needed now is more information as to the course followed by evolution, in order to complete our knowledge of phylogenetic taxonomy.

ACCOMPLISHMENTS OF EVOLUTION

The millions of individual plants and animals covering the earth and constituting thousands of species are looked upon as so many products of evolutionary development. What the first form of life was, whether it originated at a single point or several, and whether or not plants and animals had a common ancestry are questions that cannot be answered now. Every form of life we now have shows a complexity of structure far beyond what must have been possessed by its remotest ancestor.

Much evidence points to the conclusion that during the vast eras of organic development periods of accelerated progress took place. Conspicuous in the plant kingdom was the advent of alternation of generations. Prior to this epoch-making event changes appear to have been relatively slow. With the appearance of a progressive sporophyte, alternating with a waning gametophyte in each life cycle, increase in complexity appears to have taken place by leaps and bounds. It is not unlikely that more time was required to make the first liverwort than to go from that point to spermatophytes like those of today.

It is a significant fact that while some forms progressed rapidly others were relatively stable. Had all changed equally we should have no lower plants and animals now. Doubtless all have changed more or less from their ancestral forms, but some relatively little. This fact is a great help in the study of phylogeny, for the progressively higher forms may be compared to a series of pictures of evolution, taken as it marched past.

BASES OF TAXONOMY

All modern tendencies are toward making phylogeny the underlying principle of taxonomy; but phylogeny is not in itself a tangible thing that appeals to the senses. We must, then, have a usable criterion that will indicate phylogenetic relationships.

Morphology as an Indicator of Relationships. Morphology is the most widely used instrument of classification. This was true before the time of Darwin and it is so today, though we now

use it more intelligently in the light of our knowledge of evolution. An indicator to be useful must be fairly easy of application and reasonably accurate. Genetic relationships usually express themselves in similarities and differences in form and structure. These different characters are in themselves numerous, and considered collectively they present almost endless combinations. Also, morphological differences appeal to the eye, usually on brief inspection, and offer a rapid means of classification. Morphology does not suffice, however, in certain groups of lower plants, particularly pathogens, where similar-looking fungi and bacteria cause different diseases, and in the *Fungi Imperfecti*, where only asexual reproduction remains in plants once possessed of varied sexual stages.

In the use of comparative morphology one must discriminate between homologous and analogous structures (see p. 22), as the former are usually significant while the latter are likely to mislead.

Physiology as an Indicator of Relationship.—It is a well-known fact that groups of plants differ more or less in their physiology. These differences may be either qualitative or quantitative, and may or may not be accompanied by morphological differences. Physiology, however, is a cumbersome basis for classification. If we had to perform a series of physiological experiments to tell one species from another, progress would be slow. Furthermore, the usual physiological processes, especially among chlorophyll-bearing plants, are not established as dependable criteria of species. In many cases they are too unstable, for in response to changes in environment, heat, light, food, moisture, etc., plants show changes in physiology much more readily than in morphology. For this reason, physiological differences are little used except to supplement morphological ones, as in the lower groups just mentioned where the latter alone are not sufficient. It seems unwise, however, to rule out physiology entirely, as some systematists have been inclined to do, especially as serum diagnosis (see p. 52) may be interpreted as a physiological reaction. Such an attitude has the effect of discarding a tool that is sometimes useful.

PROGRESSIVE AND REGRESSIVE DEVELOPMENT

As a matter of convenience and in accord with our narrow human standards we say that genetic lines have either progressed or degenerated. These terms must be used with caution and

may be misleading if the situations to which they apply are not closely analyzed.

Indications of Upward Development.—Upward or progressive development generally implies an increase in qualities beneficial to the race.

Increase in size is usually looked upon as progressive. In general, the higher plants and animals are larger than the lower ones, though there are numerous exceptions. Tall plants may be able to reach the light where shorter ones would be deprived of it. Large animals may be able to overcome smaller ones in combat, other conditions being equal. Size, however, may become a hindrance, especially among animals, where food is scarce or where the ground has become too soft for locomotion. In all likelihood this aided in the extinction of certain huge prehistoric reptiles and mammals.

Increase in specialization is a more certain indication of advanced development. The development of heterospory, stomata, root-hairs, and palisade tissue in leaves, to take the place of less-differentiated structures, are familiar examples. Indeed, in the lower plants one cell or a simple filament may perform in a crude fashion the functions of all of these.

Quite clearly there may also be danger in specialization, either because the specialized organ becomes an encumbrance, or because of the fact that with specialization of a given structure to do certain work there comes to be a lessened ability on the part of other structures to do equivalent work. When conditions are right for the specialized organs to function effectively, the plant prospers, but with altered conditions more conservative structures may save the race. Two examples will make this clear. If conditions were favorable for insectivorous plants to obtain most of their nourishment from their prey and other food were scarce, specialization of "fly traps" with the inevitable reduction of other organs of nutrition would be advantageous; but should the supply of insects fail, the more conservative ancestral forms would be more likely to survive. Xerophytic structures are well adapted to arid conditions, but a xerophyte in a swamp would be worse off than a mesophyte.

It is now agreed that the plants and animals with organs highly specialized in one direction are not usually the ones from which higher groups evolved. These greatly specialized groups more often form side branches to the main genetic stem, which shows

progressive evolution. It is doubtful if *Pilobolus*, *Hydrodictyon*, *Marchantia*, or the specialized orchids and insectivorous plants have given rise to any important groups.

Specialization of animals has far exceeded that of plants, particularly in the various methods of locomotion and in the marvelous development of the nervous system and special senses. Correspondingly they appear to have suffered more than plants from excessive specialization in directions that were an obstacle under changed environmental conditions.

Forms of Degeneracy.—It is in a study of so-called degeneracy that we need to think our way most carefully. It is usual to regard any loss of structures or functions once useful, or any increased tendency to be dependent on other forms of life, as degeneracy. The question is largely one of definition and interpretation. The conspicuous example of degeneracy in the plant kingdom is loss of chlorophyll. It is probable that the first living things on the earth had no chlorophyll and that its acquisition was one of the greatest events in the history of the organic world. The ancestors of the fungi appear to have acquired it and later lost it. So also with the Indian pipe and a few other angiosperms. If planted in an environment of abundant and suitable organic matter with little light, these plants thrive better than their chlorophyll-bearing relatives; but if stranded in an inorganic environment they perish. It is a well-established fact that plants that have completely lost their chlorophyll never regain it.

Parasitism is another form of degeneracy common among plants and animals. Strict parasites thrive when associated with certain hosts, but not elsewhere. Strict or obligatory parasites are, however, rare; most parasites retain saprophytic power which they use in times of necessity.

When it is remembered that all vestigial structures (see p. 11) are products of degeneracy, that they are usually the result of adaption to a changed environment, and that they are especially prevalent in the higher forms of life, we see that it is necessary to give a liberal interpretation to what is usually called degeneracy.

Evolution is Irreversible.—In 1892, Louis Dolle, a Belgian paleontologist, put into concrete form a principle that had been vaguely felt by others. As restated in 1901, it is as follows: "An organism never exactly renews a previous condition, even if it finds itself placed in an environment identical with one

through which it has passed. But, by virtue of the indestructibility of the past, it always retains some trace of the intermediate stages which it has traversed." This "law of irreversible evolution" has many applications in both botany and zoology. When organisms have become profoundly changed through adaptation to environment and then have been resubmitted to the earlier conditions, they have not gone back to ancestral types but have become adapted through new modifications. We hold that at one time all plants were aquatic, that some of their progeny developed terrestrial habits and structures, and that some of the progeny of these terrestrial plants became aquatic again; but in doing so they certainly did not become marine algae, like their ancestors.

A few examples of apparent reversibility, however, may be found in certain organs among flowering plants. There is little doubt that primitive evergreens gave rise to deciduous plants, some of which in turn became evergreen. Apparently quite frequently plants with two leaves at a node gave rise to others with one leaf at a node and vice versa, although in all probability all came from ancestors that were uniform with respect to the arrangement of leaves on the stem. Broad leaves have given way to narrow ones and vice versa. Furthermore, herbaceous plants have arisen from woody forms, and in a few cases they have given rise to woody forms again. It may be argued that the newest product is not a true reproduction of the ancestral one with respect to the quality in question but, nevertheless, the apparent reversal may mislead the student of evolutionary tendencies.

It is quite possible that some minor changes, especially those of physiology, require some time to become permanently established, and that before that time is complete, they may, by a reversal of environment revert to an original condition; in the main the law holds true, however, and is a great guiding principle. It may seem to conflict with the belief in "reversion to type," but so little is known of the underlying principles of this so-called "reversion" (except as an expression of recessive Mendelian characters or recurrence of primitive factorial combinations) that it does not weigh heavily against Dolle's law.

CHAPTER III

PRINCIPLES OF TAXONOMY

As a result of centuries of study and discussion, botanists and zoologists have learned much that is essential to logical classification. There is now a pretty general agreement on the main principles, and a fair uniformity of practice, excepting in certain detail where much difference still exists.

CATEGORIES USED IN TAXONOMY

The term "category" is used to designate any *definite* group, large or small, into which plants or animals are classified. Genera, species, families, etc., are examples.

For convenience and uniformity, a rather definite series of categories for the plant kingdom has been adopted. The regular categories, ranging from the largest to the smallest, are as follows: kingdom, division, class, order, family, tribe, genus, and species. These terms have each been given as definite a meaning as possible, and they must not be used loosely or interchangeably.

Most categorical names have, for convenience, definite endings. The names of all groups larger than genera are given the plural form. The names of orders usually end in -ales, those of families in -aceae, and those of tribes in -eae. The following is an example showing the sequence of categories and the proper endings.

Division Spermatophyta
 Class Angiospermae
 Order Rosales
 Family Rosaceae
 Tribe Roseae
 Genus Rosa
 Species rugosa

In special cases the qualifying prefix "sub" may be added to any of these, as subclass, subgenus, etc. This practice is a matter of convenience where the group contains many members and

especially if these members fall into two or more natural groups. In this way the class Angiospermae is commonly divided into two subclasses, monocotyledons and dicotyledons.

By some authorities varietal names are not generally recognized in botanical taxonomy, this category being relegated to horticultural and agricultural usage, and applied most frequently to cultivated forms, improved in some particular by the plant breeder. Another tendency is creeping into use, however. Among the fungi and bacteria the different individuals that make up a species may be alike morphologically, but different physiologically and are therefore given varietal names. Thus we have *Puccinia graminis tritici* and *Fusarium martii phaseoli*. There are arguments for and against varietal names. On the one hand we are committed to a binomial system of nomenclature, using only the generic and specific names; and the recognition of varieties extends this to a trinomial or even polynomial practice. On the other hand, there are cases where very minute distinctions need to be made for economic or for scientific purposes. There may even be cases where different strains of a variety of a given species will be recognized, and there are serious objections to making separate species on such fine points. The "biological races" of parasitic fungi cited above, and the "types" of such human pathogens as *Diplococcus pneumoniae*, and *Clostridium welchii* are virtually equivalent to varieties. These distinctions are necessary and we have the alternatives of calling them different species, varieties, or less-recognized categories, such as types and races. They must not be confused with strains which are often practically identical except for the history of their origin and culture. A fuller discussion of subspecific categories will be found near the end of this chapter.

Where an indefinite term is needed the word "group" is generally preferred. Thus any one of the categories mentioned above may be called a group, or the term may be applied to any other collection of individuals in any way related.

The phylum in zoology is a definite group consisting of related classes. In botany the phylum is not generally recognized as a regular category. It is, however, a most valuable group ranking usually between the class and the division. The phylum is constructed on logical phylogenetic lines. The division, on the other hand, is usually a heterogeneous collection. It exists because we have neglected to abandon it.

There is no uniformity in size among the categories. One genus may contain dozens of species, and another only one or two. Except to satisfy a desire for uniformity of procedure several categories might have been omitted in the smaller groups. For example, *Moschatellina* is the only species in the genus *Adora*, which is the only genus in the family Adoxaceae. If all families had been as small or even contained but a half-dozen genera, probably families and tribes would never have been devised and orders would have been divided directly into genera. In actual practice tribal names are not often used excepting in the larger families, and the ordinal names of the higher plants are rarely heard, and are omitted from most of the manuals of this country.

MAJOR AND MINOR CHARACTERS

The higher plants are so complex and have so many different characters that the early botanists were greatly perplexed to know which features were important for taxonomic purposes and which unimportant. Naturally those of greatest importance would be used as a basis for main divisions, and those of lesser importance for the subdivisions. They made the fundamental mistake of classifying the higher plants primarily into trees, shrubs, and herbs. Each of these was then subdivided into smaller groups. The beginning student in systematic botany has a similar problem. He wishes to know which characters should be family distinctions, which species distinctions, etc., and which are too unreliable to have a taxonomic value.

In modern taxonomy an effort is made to have the larger groups—classes for example—show the more ancient phylogenetic branchings and the smaller groups, such as genera and species, show the more recent branchings. The question then arises which morphological characters indicate ancient and which indicate recent origin. These points have now been fairly well established, and the student of today can be guided to some extent by studying the classifications and the analytical keys in use, and noting the characters used for distinctions between classes, families, genera, species, etc.

Stability.—Almost without exception the more stable structures indicate ancient phylogenetic departures. If plants differ with respect to these structures the differences have existed for a long time. Among the spermatophytes the presence or absence of coverings for the ovules and the distribution of fibrovascular

bundles are examples of such major characters. On the other hand, unstable qualities such as length of stems, breadth of leaves, and color of petals indicate more recent changes and may be called minor characters. Naturally there will be characters of intermediate rank as well.

Vegetative versus Reproductive Structures.—The older classifications were based mostly on vegetative parts, no *especial* attention being given to flowers and fruits. Linnaeus, about the middle of the eighteenth century, first emphasized the advantages of using reproductive parts in classification. He used no vegetative characters for describing genera. At the present time morphological characters of all kinds are used but the reproductive parts are most emphasized. Practically the only vegetative structures of major importance for purposes of taxonomy are those of the fibrovascular system of stems and leaves. Carpels, stamens, and petals are of almost equal rank with fibrovascular structures, and because of their greater variety have a much wider range of usefulness.

Clear-cut versus Intergrading Characters.—Those major characters that are used for dividing the spermatophytes into classes have long ago reached a state of equilibrium. They are now clear cut. Intergrading conditions between flowering and flowerless plants, and between the enclosed and the naked ovules can be imagined, and may have existed at one time, but apparently do not exist now. Likewise the characters used for dividing the class angiosperms into the subclasses monocotyledons and dicotyledons, namely number of cotyledons in the seed, distribution of vascular bundles in stems, and character of venation in the leaves, show very few intergrading forms at this time. Minor characters, however, are very likely to be intergrading. There may be every degree of pubescence, of floral coloration, and of size of leaves. Some gradations are clearly expressions of environment. It is likely that others express evolutionary branchings so recent that the types have not yet become fixed. They may be purely differences of degree, and represent a condition in which certain individuals, strains, varieties, or species have advanced farther than others in the same category.

It is common taxonomic practice, based on experience and reason, to hold more closely to major than to minor characters. If a plant shows any departure whatever from a written descrip-

tion with regard to a major character it is usually rejected at once from that group. If it fails to agree in an intermediate character such as number of petals or dehiscence of fruit, the identity is strongly questioned. The plant may, however, differ, in degree at least, in one or two minor characters, but the more of these it violates the more doubt is thrown upon the identity. It may be said in this connection that related species sometimes hybridize in nature, thus increasing the difficulty of identification. Certain oaks and willows are examples.

Homologs versus Analogs.—Morphological comparisons may mislead one unless he has a fundamental understanding of homologous and analogous parts. Structures similar in appearance and function may be homologous, *i.e.*, specialized from the same part of the plant—root, stem, or leaf—or they may be only analogous, *i.e.*, specialized from different parts. The leaf-like cladophyll of common greenhouse smilax is analogous to the true leaf, as is also the so-called leaf of the moss which is a part of the gametophyte generation. Analogous structures are similar in appearance, but homologous structures may or may not resemble each other. The cladophyll just mentioned, the thorn of the hawthorn, and the tuber of the potato are all homologous with stems. It may be stated as a general proposition that where the structures performing a given function in two plants are only analogous, these plants are not closely related. For example, it is rare to find in the same genus one plant with tendrils that are specialized stems and another with tendrils that are specialized leaves. The same may be said with regard to thorns. Likewise, large, colored, petal-like bracts do not usually occur in the same genus with large-petaled flowers. Analogous structures are rather strong, then, in indicating differences. No very general rule can be laid down, however, for homologous structures. They are so numerous and so varied that they may indicate any degree of relationship.

Special Structures.—Remarkable development in one direction characterizes certain plants, notably the devices for catching insects, the floral structures of the orchids, and various xerophytic adaptations. These must be regarded as moderately strong characters for purposes of classifying the plants possessing them, but they have a very limited application.

Habitat.—Many descriptions include the habitat. This has value as a suggestion but is treacherous as a character for classi-

fication, since the agencies for plant distribution may carry some individuals far from their usual haunts. Under these circumstances there may be considerable variation from the written description of the species, as environment determines in some measure the size, breadth of leaves, succulence, hairiness, etc.

Ease of Comparison.—For generations botanists have fought a tendency to give undue importance to certain superficial characters that result in artificial groups. It may have been found convenient to call all the lower plants that have no chlorophyll fungi, all plants producing an archegonium Archegoniatae, all seedless plants in which both gametophyte and sporophyte penetrate the soil and produce leaves pteridophytes, and all seed-bearing plants spermatophytes; but to regard any of these groups as phylogenetic units, in the light of present knowledge, is a monstrosity on a par with classing butterflies and bats with birds. Tendencies of this kind on a smaller scale are numerous. Such artificial groups may be recognized under common names such as fungi and seed plants, but we should, where possible, avoid such technical or scientific names as Hyphomycetes and Spermatophyta. Hyphomycetes and Archegoniatae are now practically obsolete, and Pteridophyta and Spermatophyta are becoming so. One of the greatest duties of the systematic botanist is to find the natural system of classification and to present it in a form that will be scientifically correct and yet convenient enough to gain recognition in a world where efficiency is a valued attribute.

CHARACTERS OF SPERMATOPHYTA

It would be very convenient if we could say that one character is always used for class distinctions, another for family distinctions, another for generic distinctions, etc. Were plants perfectly standardized in their morphology this could be done; but they are not. We must, therefore, make the best of conditions as we find them. It is so desirable, however, to give the student some idea of the methods by which the different categories are distinguished that a discussion of the values and uses of the more prominent characters will be given.

Probably all botanists agree that a phylogenetic arrangement of the flowering plants is like the trunk and branches of a tree. One conception of it is illustrated in Fig. 2, page 56. It is important to remember in this connection that the same char-

acter (apetalous or gamopetalous flowers or united carpels, for example) sometimes appeared later in one group or phylogenetic branch than in another, as a separate evolutionary act, and may therefore be used either as an ordinal, a family, or a generic distinction. Most important of all in interpreting the significance of different characters is the fact that phylogenetic groups are based not on *single* characters but on *combinations* of characters. To divide the angiosperms into two subclasses, one consisting of all plants having simple leaves, and the other of all plants having compound leaves, would be absurd, and unquestionably artificial.

Roots.—When bulbs, tubers, rhizomes, etc., which are not properly parts of the root system, are excluded, underground parts have but a limited taxonomic value. Roots are hard to observe, and having no division into nodes and internodes, they are relatively characterless. Also, they are much affected by the character of the soil. For these reasons many descriptions make no mention of roots, and they are rarely used for specific or generic distinctions, though in some families, such as Cruciferae, tap roots are the rule, while in others, such as Gramineae, the roots are mostly fascicled.

Probably the most usable character of roots is their longevity. On this basis plants are divided into annuals, biennials, and perennials. The strength of this character varies considerably, being mostly a family or a generic distinction.

Stems.—In early times stems were very much used in classifying plants, and even today their importance is not minimized. One of the strongest characters found in higher plants is the distribution of fibrovascular bundles. It is generally agreed that, if spermatophytes only are considered, the arrangement in a cylinder, illustrated by the gymnosperms and the dicotyledons, is the more primitive form, and the scattered arrangement in the monocotyledons is derived from it as a more recent departure although we must concede the likelihood that remote fern-like ancestors of the gymnosperms had scattered bundles also. The number of leaves and buds at the nodes may be looked upon as a character of the stem rather than of the leaf. This character is of intermediate value, being usually a family or generic distinction, but it is sometimes specific. The degree of lignification of the stem, distinguishing trees and shrubs from herbs, is now regarded by most authorities as an intermediate character. Some families

are wholly woody and a very few wholly herbaceous, but most of them are mixed. The distinction is usually a generic one. Ancestrally the woody stem is the older. Branching habit is a very weak character often determined by environment, and seldom used for categories larger than species. The trailing habit of vines is an intermediate character of generic or family importance.

Leaves.—The taxonomic value of leaves is about on a par with that of stems. Primitive leaves were probably simple rather than compound, and had branched or netted veins. The venation is a character of major importance, being one of the distinguishing features between dicotyledons and monocotyledons. It should be mentioned, however, that a few of the monocotyledons, as *Smilax* and *Trillium*, have netted-veined leaves, though the venation here is closed rather than open. The compounding of the leaf is an intermediate character. Usually it is a family or even an ordinal distinction, but sometimes it has only generic value. In the family Rosaceae, particularly, there is a lack of uniformity. The fact that some leaves are evergreen and others deciduous is often of value in classification. The evergreen condition is generally recognized as primitive, although it is probable that some evergreen angiosperms had deciduous ancestors. The character has usually a generic value as there are no large families of angiosperms entirely evergreen.

The form of simple leaves is a weak character, generally used along with others to distinguish species.

Epidermal hairs are considerably used for specific distinctions, but they have little value for the higher categories.

Inflorescences.—Mention has been made of the strong modern tendency to emphasize reproductive structures in taxonomy. No doubt the solitary flower, probably typifying the strobilus or cone of the pteridophytes and gymnosperms, is more primitive than the collective inflorescence. Inflorescences have an intermediate rating usually of generic value, although some families are uniform as to type. Some trouble is given here by intergrading characters, as racemes grade into spikes, and both racemes and spikes grade into heads.

Flowers.—In comparative morphology the flower is usually regarded as a specialized strobilus in which the lower sporophylls have become sterilized to form sepals and petals, and the upper have changed into stamens and carpels. Unfortunately, fossil

remains that show the details of transition are wanting. The axis of the strobilus is shortened to form the receptacle of the strobiloid or hypogynous flower of the primitive type. This occurs regularly in lower monocotyledons and lower dicotyledons. In the eotylid or epigynous flower of the higher monocotyledons and dicotyledons, the axis is actually depressed into a cup containing the carpels. This is usually an ordinal or subclass distinction, but in some of the transitional families there is lack of uniformity among genera.

Aside from the flower axis the carpel is the most important organ taxonomically. The primitive condition is that of many separate carpels, reduction in number and union to form a compound pistil being a later development. Carpellate variations are, for the most part, major characters used for ordinal and family distinctions, though in respect to certain details such as number and length of styles a lesser rating must be given them.

There is some tendency to reduction in number of ovules with upward development.

Stamens are of considerable importance in classifying plants. Decrease in number, union of filaments, and sterility of anthers are among the newer developments. They have an intermediate rating, usually for family or generic distinctions. The point of insertion relative to the petals is of considerable importance. Absence of pistils or stamens, resulting in unisexual flowers, may be looked upon either as degeneracy or as a form of specialization whereby the likelihood of close pollination is reduced. It is generally either a family or a generic distinction.

The perianth is usually regarded as a system of strobilate leaves that long ago ceased to produce spores. The calyx is rarely absent but presents so little variation that its taxonomic value is limited. Color, other than green, is a derived quality. The corolla is much used in classification. It is relatively easy of observation, and it presents much variety. The primitive form is of many separate petals symmetrically arranged on the receptacle. The union to form gamopetalous flowers must be given a variable rating. Whole orders show this character in the higher dicotyledons, but it has developed to a limited extent elsewhere in families otherwise polypetalous. Apetaly is a somewhat weaker character of family, generic, or even specific distinction. Irregularity of corolla is usually a family distinction but may be generic. The color of petals is usually a weak charac-

ter. The orange and deep yellow colors are quite dependable, but gradations from white through pale blue or purple to violet are common and may be misleading.

Pollen Grains.—Taxonomists have been prone to overlook an important set of morphological characters, those of the pollen grains. It has been shown that these are reasonably constant for each species and that related species generally have grains quite similar in certain respects. The chief characters of pollen grains are size, general shape, germinal apertures, and surface markings, such as spines, ridges, and furrows. It will be noted that while most morphological characters of higher plants are expressions of multicellular structures, those of pollen grains are characters of the individual cell. These have long been used in classifying the lower plants, especially the fungi. In addition to the morphology of individual grains, the pollen masses show considerable variation, in some being powdery and in others waxy or viscid. Pollen characters have family, generic, and specific value.

Fruits and Seeds.—For purposes of analytical keys it is best not to depend too strongly on fruits and seeds, for much identification is done with immature plants. Although some of these characters, such as the numbers of seed chambers and ovules, can be determined from the flower pistils or young fruits, other qualities such as size, color, fleshiness, and dehiscence of fruits, and size, shape, and markings of seeds develop later. These are for the most part rather weak characters, with the exception of the method of dehiscence. More dependable characters are the number of cotyledons, the presence or absence of endosperm, and the position of the embryo.

The special art has been developed recently in agricultural work of identifying plants, particularly weeds, by seed characters alone. Skill in this field has considerable value in detecting impurities in seeds of cultivated plants. In some cases seed characters are sufficient to distinguish species, in others only generic identification is feasible.

Summarizing this discussion, several points are to be emphasized: (1) that in defining the different groups of plants, combinations of characters must be considered; (2) that evolution is going on all the time causing certain characters such as unisexuality, irregularity of flowers, compounding of leaves, and saprophytism to appear repeatedly and independently in different

groups; (3) that occasionally, perhaps by coincidence, similar combinations of characters appear in different groups resulting in like individuals of different ancestry (polyphyleticism); (4) that there have been certain general tendencies in the evolution of the flower, notably reduction in number, fusion, and specialization of parts; and (5) that only approximate taxonomic values can be attached to most of the characters used for classification.

PLAN OF TAXONOMY

Taxonomy must be looked upon as an artificial attempt by man to express similarities and differences occurring among individuals. The mind of man cannot comprehend each separate individual of the millions of plants on the earth, hence it is necessary to think of them in groups, generalizing their characters in so far as it is safe to do so. This necessity and the orderly tendency of the scientific worker have led us into many of our taxonomic problems.

Categories should be made to fit plants, as plants cannot be changed to fit categories. As a forerunner to the categories we now have, certain group entities were noted many years ago. Some of these were small groups, others large, including the small groups and additional ones. Thus the flowering plants were thought of as a very large group including legumes, mints, umbellifers, daisies, etc., and legumes were known to include various kinds of clovers, vetches, peas, etc. Centuries of study yielded a mass of information about groups of plants, and we have attempted to make usage more uniform by adopting the system of categories already studied. Always we must think of them as man-made attempts to simplify and express a complex, unstandardized, and constantly changing mass of living things. Under these conditions absolute exactness is impossible, and approximate exactness must be tempered with convenience. Inevitably there is and will be some difference in practice.

What Constitutes a Species.—To give categories a definite meaning there must be a starting point. To say merely that an order is a collection of related families, each of which is a collection of related tribes or of genera, does not give a full comprehension of the meaning of these terms. Other authorities look upon the species as the unit of classification, and then build the higher categories upon this conception. Still others prefer to consider the genus the unit and yet others the "race" (virtually

equivalent to variety), or even the individual. As most species are made up of individuals so nearly alike that no need has been felt for a finer subdivision, it best suits the majority of botanists to use the species as the classification unit, subdividing it into varieties or races only in those plants where such a procedure serves a useful purpose.

One of the most troublesome problems in taxonomy is to arrive at a definition of a species upon which all can agree. There are two conceptions, each having a considerable following. Certain botanists, notably De Candolle, Linnaeus, and Gray, constructed their species along bold and clear-cut lines, each species being separated from its relatives by distinct and easily differentiated characters. Trivial differences were ignored, particularly those that were only matters of the degree in which minor characters were shown. In some of Linnaeus' species, the different individuals showed considerable minor variation. In others they were essentially alike. Linnaeus' species lacked uniformity of character, however, because some of his work was compilation based on plants he had never seen. This broad method of species-making reached its greatest perfection in the work of Asa Gray. By his usage the number of species was kept relatively low, and identification of plants to the species was comparatively easy. The expression "Linnaean species" has come into accepted use for these bold, clear-cut groups, and it will be used here, although "Grayan species" may be a more accurate term.

A newer conception is that of "elementary species" or "primary species." It is practically true that no two individuals are exactly alike. In an elementary species the individuals must be as nearly alike as though they had the same parentage. This idea involves the necessity of making separate species of all plants showing any constant differences whatsoever, no matter how trivial or minute, and in some species so made they are not even constant. It will be readily perceived that this plan, if carried out, would vastly increase the number of species to be dealt with. *Draba verna* L. is cited as an example of a species of the Linnaean and Grayan kind that could be divided into more than a hundred elementary species. Where intergrading characters are found there may be almost as many elementary species as individuals. Such a system becomes burdensome, and detracts from the usefulness of taxonomy. Furthermore, where "species splitting" has been carried to such extremes, as in the

genus *Crataegus*, the specific distinctions are so hard to follow that only the specialist in that group can carry on the identification.

Subspecific Categories.—If one accepts the simpler Linnaean type of species, where minute differences are ignored, he will be obliged in some cases (as stated at the beginning of this chapter) to recognize subdivisions of specific groups. Such subdivisions are already recognized both for economic and for scientific reasons. Thus we have many kinds of apples to which are applied common names (Baldwin, Ben Davis, etc.) intended to indicate "varieties" of the species *Pyrus Malus*. Some botanists use more technical "varietal" names, as *Pyrus arbutifolia* var. *atropurpurea* and *Fraxinus pennsylvanica* var. *lanceolata*, in the seventh edition of Gray's "New Manual of Botany." There are dozens of "biological races" of the rust fungus, *Puccinia graminis*, based on varying ability to attack different grains and grasses. Bacteriologists recognize several "types" of *Diplococcus pneumoniae*, distinguished by their positive or negative precipitin reactions with the serum of pneumonia patients. Ecologists speak of "ecads," "variants," etc., among flowering plants.

The economic necessity for most of these subspecific distinctions is easily seen. The scientific aspect lies in the fact that most subspecies are results of a plasticity that has expressed itself in recent evolutionary changes and that may be still active. B. M. Davis¹ has designated as "pure" species those that, through pure lineage, have become fixed in type, and as "impure" species those of mixed lineage and subject to further variation, resulting in new species or subspecies.

In such cases as these it seems desirable to have a subspecific name or number to be used with the specific name as a trinomial where fine distinctions are needed, but omitted in more general discussions. Such a plan would be much more convenient than one that gives a separate "elementary" specific name that everyone would be obliged to learn with its accompanying hair-line distinctions and intergradations, and that fails to show which members are most closely related.

Ecologists have pointed out the desirability of designating by the subspecific name the method of origin of the form in question. Thus an *ecad* is a form arising by adaptation to environment.

¹ Species, pure and impure, *Science*, **55**: 107-114, 1922.

A *variant* is a form arising by variation. A *mutant* is a form arising by mutation and a *hybrid* is a form arising by crossing of related species. F. E. Clements¹ suggests the following methods and examples for indicating the different origins of subspecific groups:

Cerastium oreophilum = *Cerastium strictum* scias: ecad

Verbena intermedia = *Verbena stricta hastata*: hybrid

Aquilegia jamesii = *Aquilegia coerulea peralba*: mutant

Machaeranthera aspera = *Machaeranthera viscosa aspera*: variant

Such a system would give subspecific names a very significant meaning, but an enormous amount of work would be required before it could be put into effect, for undoubtedly many groups now rated as elementary species by certain authors should be transferred to a subspecific category and their derivation would have to be determined by field experiment, not by examination of existing herbarium specimens. Such experiments would be of fundamental and far-reaching value.

One taking an impartial view of the species question is forced to this conclusion: that for most of the plant kingdom the bold Linnaean type of species is simpler than the finely divided elementary species, and serves every essential purpose; but in certain groups it is necessary to make finer distinctions for research reference, though even there the majority of botanists may not need to do so for their more general work. The natural answer is to assemble the individuals into relatively few, large, clear-cut species and where necessary have additional fine distinctions to be used only by those who have special need for them. Various terms have been used to designate these finer divisions, such as subspecies, varieties, races, types, and forms. It has been suggested by N. L. Britton² that they be merely numbered rather than named and this plan has much in its favor. To be sure this introduces the trinomial nomenclature, but if this is cumbersome it has the advantage of showing relationship, for the specific name connects the subspecies to each other and the plan finds precedent in the type numbers of certain pathogenic bacteria.

Effects of Environment.—Varieties or races based on fine distinctions of a somewhat permanent character must not be confused with ecological or environmental forms of a temporary

¹ An ecologic view of the species conception, *Am. Nat.*, **42**, 264, 1908.

² The taxonomic aspect of the species question, *Am. Nat.*, **42**, 242, 1908.

nature. It is well known that closely related individuals growing in different habitats may vary considerably, so much indeed that they are sometimes called different species. It would be desirable, though sometimes impracticable, to have representatives of related species grown side by side for comparison. Such a test would eliminate many superfluous specific names from our manuals. It would also involve, in some cases, the practice of including in the specific description qualifying statements concerning the effect of environment, and corresponding records showing the habitat of the specimen in question. The work now being done in this field by ecologists will greatly strengthen our taxonomic systems.

Generic distinctions, and those of higher categories, give much less trouble. To be sure there is some difference of opinion as to what categorical rating should be given to certain groups, *e.g.*, whether they should be considered orders or families, families or tribes, genera or subgenera. In fact several families have been divided in recent years, and some would now call the legumes and the composites orders rather than families. These differences are not disturbing, however. Because of the absence of gradations in characters used in class, order, and family distinctions there is usually little difficulty in placing a plant correctly in these groups, and even generic classification is seldom troublesome.

CHAPTER IV

DIFFICULTIES IN CLASSIFICATION

Botanists have been working for centuries upon the classification of plants, and while much has been accomplished the end is a long way off, and some groups may never be classified satisfactorily. Some of the difficulties are due to the character of the subject and others to its magnitude. If, for example, classification were limited to the fungi of the British Isles, we would have many perplexities through loss of ancestral forms; but when we consider all the other groups of plants throughout the world, made up of countless individuals and covering areas so vast that some have not yet been seen by civilized man, we are forced to concede that taxonomy is one of the major enterprises of science.

DIFFICULTIES DUE TO SCOPE OF SUBJECT

The pioneer in any subject makes some mistakes and the early systematists were no exceptions. The magnitude of the work was so great that, with no organization among themselves and no governing standards, they labored at a great disadvantage.

The Logical Procedure.—If all the taxonomic work were to be done over again the logical procedure would be to assign different parts to different workers who would confer from time to time to coordinate the units into a harmonious whole. This task began, however, when science was in its infancy, and such an organization was not even dreamed of. Clearly the undertaking was too great for one man or one generation. None of the earliest botanists had a vision of the entire enterprise, and none could have carried it through if he had. Furthermore, the early work was purely voluntary and done mostly by men who carried a heavy load of other duties.

Work Done Piecemeal.—The natural procedure was followed. Each man studied the group of plants that happened to attract him, but many groups were neglected. Most of our best taxonomic work has resulted from group specialization. Naturally those plants that were conspicuous or had an obvious economic

significance received the most attention. When later botanists with a broader vision attempted to summarize the results and record them in more general systems of classification, they naturally encountered several difficulties.

In the first place, many of the plants had been left unclassified, so they had to be placed in heterogeneous groups for further study, or tentatively attached to groups where they did not belong, and in the second place, the better-known groups had been classified by different methods, from different viewpoints, and using different characters. Some groups were so poorly constructed that they had to be entirely rebuilt, others were more or less modified, and still others were used in an imperfect form. The result is our present system of classification, good in spots but weak in others, and not well coordinated. It is almost as though we selected from our literature a hundred of the best short stories and put them together in an effort to make one great novel. Lack of cohesion would be one of the conspicuous features even with the most careful editing.

Restrictions of Travel.—There is a good deal of variation in the floras of different countries. Botanists have never been able to travel enough to compare all these different floras, and this difficulty was far greater in the early days than now. As a result classifications have been made up on too limited evidence. Herbaria with representative specimens from different countries and habitats have improved the situation to some extent, but most herbaria are very fragmentary.

Limited Publication.—The next best thing to seeing plants is hearing or reading about them. Much of our classification was made when botanical journals were unknown and the meager writings in one language were little read by those speaking another. Many species that had been discovered and named were rediscovered and given other names by those unaware of the previous work.

The whole effect of the lack of intercourse and travel was to burden the tottering schemes of classification with duplicate names, synonyms, faulty descriptions, and a confusion of tongues.

DIFFICULTIES INHERENT IN THE SUBJECT MATTER

The desire for a classification was felt before the machinery was ready for making one. We began to classify plants with no intimation of evolutionary origin, little knowledge of physiology

or morphology, and no microscopes for aiding the eye in a study of tiny plants and the finer structures.

Pre-evolutionary Classification.—Prior to the work of Darwin, the viewpoints of classification were quite different from those that prevail today. Then there were two methods more or less used. One was to group plants according to economic uses, and the other according to gross similarities in appearance. No attempt was made to work out phylogenetic relationships for none were known to exist. Much stress was laid on the definition of a species for each species was assumed to have been created separately; hence relationships of individuals within each species were recognized, but none between different species, although some spoke of “natural affinities”—an expression of rather uncertain meaning.

Some quite elaborate systems of classification had been proposed before the doctrine of evolution was set forth. These systems, lacking the phylogenetic viewpoint, were more or less artificial, but it reflects credit upon morphology as an index to phylogeny that the classifications of Jussieu, De Candolle, and Endlicher (see Chap. V) had much in common with those of today. Doubtless these could have been improved by further morphological study even without a knowledge of evolution.

The belief in the evolutionary origin of species has necessitated considerable readjustment of the older systems, but not a complete revolution. Chiefly it has served as a guide in the reclassification of the more difficult parts of the plant kingdom where purely morphological characters had not been fully comprehended and interpreted. It has given a wholly new significance to comparative morphology.

Late Invention of the Microscope.—Had the microscope been in general use throughout the development of botanical science the lower plants would not have been so long neglected. Most of the older classifications either ignored these smaller forms entirely or threw them into a chaotic unsorted group. Lack of the microscope also delayed the discovery of complex life histories which have been found so significant even in such large plants as ferns and angiosperms.

Loss of Ancestral Types.—It is not too much to say that “missing links” represent the rule rather than the exception in all studies of the phylogeny of plants and animals. We do not even know how many instances of algal degeneration occurred to

make our present-day fungi, or the transitional forms between the gymnosperms and the angiosperms. Paleobotany has done much, to be sure, but it is incomplete, with many gaps, and the chronological sequence is only approximate. If we had a record of all ancestral forms it would solve most of the difficulties of phylogenetic taxonomy.

Degeneracy resulting in simplification is sometimes hard to distinguish from primitive simplicity. This fact has been troublesome in placing the bacteria, the yeasts, the *Fungi Imperfecti*, and even some of the flowering plants, "Apetalae," for example.

A Rigid System for a Flexible Subject.—John Ray said: "Nature refuses to be forced into the fetters of a precise system." Notwithstanding this dictum, we make our definite categories and try to fit plants into them. As yet we see no other way. The chief difficulty comes from intergrading characters. As previously stated, most of the major characters are not intergrading. If they were as troublesome in this respect as certain minor characters it is doubtful if our present system of taxonomy would be workable. Most of the controversies of modern taxonomists are due to three causes: (1) intergrading characters, (2) differences of opinion as to the relative value of characters, and (3) unwillingness to sacrifice mechanical convenience to phylogenetic principles.

Of the difficulties presented in this chapter all can be overcome but two, the loss of ancestral types and the fitting of intergrading characters into hard and fast categories. Paleobotanical studies will help to relieve the former difficulty and ecological studies the latter, for some of the gradations are merely expressions of the effects of environment.

CHAPTER V

DEVELOPMENT OF SYSTEMS OF TAXONOMY

It is difficult to appreciate the strength and weakness of our modern systems of classification without a knowledge of the struggle by which they came into being. Students at first assume perfection in classification and nomenclature; then as a sequel to disillusionment, they are prone to emphasize the failings and minimize the virtues, unless they are made to realize the immensity of the problem and the handicaps under which the makers of systematic botany labored.

Nomenclature Preceded Taxonomy.—There can be no doubt that people gave names to certain plants before they attempted to classify them. The first were, of course, common names in many languages and tongues. With the limited intercourse that then prevailed among peoples, and the entire lack of scientific work requiring exact terminology, these common names and the loose application of them were sufficient.

PRE-EVOLUTIONARY SYSTEMS OF TAXONOMY

Through all the centuries prior to Darwin's "Origin of Species" (1859), botanists used no one outstanding basis for classification. Up to the sixteenth century they drifted like a ship without a rudder, with classifications based on economic uses of plants predominating. Then gradually morphology came into recognition as superior to other taxonomic criteria, not at first because it was known to indicate phylogenetic relationships, for these were not recognized outside the species, but because it coincided most closely with a feeling or instinct for "natural affinities."

Taxonomy Began with the Greeks.—There are some who believe that the ancient civilizations of China and Egypt had made considerable advancement in systematic botany and the medicinal uses of plants, but if so their work had no influence on these subjects as we know them. The Greeks, notably Theophrastus and Dioscorides, were the fathers of the systematic and medical botany of today. Beginning several centuries

before the Christian Era, the Greek physicians found in some plants actual medicinal properties not to be confused with superstitious beliefs. The fame of this work spread to the Roman Empire and other parts of Europe, and created a desire for what we would now call an international system of nomenclature and taxonomy. The grouping was at first largely an economic one, however, and the nomenclature became a heterogeneous mixture of Greek, Latin, and other names, varying with the country using it. A few of the names still survive.

Aristotle, and more particularly his pupil Theophrastus, made some attempt to extend botanical knowledge beyond the scope of medicinal plants. Theophrastus¹ has well been called the "Father of Botany." Although his writings were made some three hundred years B.C., they were incomparably better than any others before the sixteenth century A.D. He clearly recognized several hundred species and a few families, although he had no system of categories such as are used today for classification. These Greek pioneers made the fundamental mistake of trying to make life processes the basis of classification; and the structures for carrying on these processes about which little was known were given a rating according to the importance of the physiological process. Nutrition was considered the most important, hence vegetative structures—unspecialized roots, leaves, and stems—were used for the main subdivisions. The writings of the Greeks embodied too few observations on what plants are, and too much philosophizing as to how they might be expected to be.

Taxonomic Development in Southern Europe.—The work begun by the Greeks languished for a time and was then revived, culminating in the philosophy and classification of the Italian, Cesalpini, in the sixteenth century. He wrote a set of sixteen volumes on plants. The first was philosophical, making much of such minor distinctions as cultivated *vs.* wild plants, trees *vs.* shrubs *vs.* herbs, and using curious mixtures of morphology and medicinal virtues. In the other fifteen volumes he divided the plant kingdom into fifteen heterogeneous groups including some animal forms. Cesalpini's work was remarkable in its attempt at that early date to classify the whole plant kingdom, and it made a profound impression on the botanists of Southern

¹ Theophrastus' "Enquiry into Plants," an English translation, shows an astonishing amount of botanical knowledge, along with some faulty deductions.

Europe, but it lacked a consistent morphological basis and little of it has survived.

Taxonomic Development in Central Europe.—Systematic botany in the central European states followed a course that was somewhat different from that developed in Southern Europe. The botanists of this central region, particularly those of Germany and Holland, were striving, first, to find and identify the medicinal plants of the Greeks and to add to the number, and then to gain greater knowledge of plants in general. To this end they studied the writings of the ancients, made extensive collections, wrote exhaustive descriptions, sometimes with illustrations, established botanical gardens, and, finally, as a result of laborious comparisons, they began to make classifications. In their first attempts, they did little abstract reasoning, but followed rather closely morphological similarities and differences, and, like Theophrastus, showed quite accurate perceptions of "natural" groupings, even though they were not at that time governed by evolutionary beliefs. The strength of their work lay in their numerous and closely comparative observations, and in the predominance of morphological characters over economic distinctions. Slow and ponderous thinkers, they did not quickly formulate complete classifications, but certain groups such as Umbelliferae, Leguminosae, Gramineae, Labiatae, Malvaceae, and a part of the Compositae became quite definite entities—oases, as it were, in the desert of unclassified plants, or crystals forming in an indefinite solution.

Some incidental contributions to taxonomy are worthy of note, especially the illustrated herbal of Brunfels (1530), the descriptive *materia medica* of Bock (Tragus, 1530), and the glossary of technical terms by Fuchs (1542), each work the first of its kind worthy of mention in botanical literature. It is believed that the Holland botanist, de l'Obel, sensed quite keenly the natural relationships of plants, for in his work, written toward the end of the sixteenth century, he grouped many plants correctly, though submitting no formal system of classification. His writings probably had much influence on the systems of Jussieu and his contemporaries.

Gaspard Bauhin, a Swiss botanist, wrote an "Introduction to Botany" in 1620, describing some 6,000 species, which had the great merit of using rather generally the binomial system of nomenclature. While Bauhin did not set forth the special value

of the binomial system or urge uniformity in its adoption, there is little doubt that his work stimulated Linnaeus to do so later.

John Ray.—The botanists of western Europe (England and France), following the morphological method to the exclusion of philosophy and economic usage, were active in organizing the fragmentary findings into definite systems. The English botanist, John Ray, in his "History of Plants," completed in 1704, proposed a system, certain portions of which have survived to the present day:

I. *Herbae*:

a. *Imperfectae* (flowerless)

b. *Perfectae* (flowering)

Dicotyledones (with two cotyledons)

Monocotyledones (with one or no cotyledon)

II. *Arbores*:

a. Monocotyledones

b. Dicotyledones

These main groups were subdivided into thirty-three smaller ones, some of which corresponded pretty closely to our present families. Others were heterogeneous, including even animals.

The conspicuous error of Ray's system is faulty subordination in giving major value to the distinction between woody and herbaceous stems, as did the Greeks and Romans before him.

Carolus Linnaeus.—The greatest contributor to systematic botany up to the middle of the eighteenth century was Linnaeus. A native of Sweden, he traveled throughout Europe visiting other botanists and making extensive comparisons of flora; and being a brilliant thinker, he was able to combine, with great powers of discrimination, the work of his predecessors and contemporaries, most thoroughly sorting the wheat from the chaff. His chief contributions were to nomenclature, those to taxonomy being indirect; for he never proposed a system of classification at all satisfactory to himself or to the botanical world. He did, to be sure, publish an artificial system based, almost exclusively, on floral characters, the stamens being given a preponderance of attention; but he realized the limited value of this scheme and regarded it as a temporary makeshift until a more natural system could be devised. This he began but did not live to complete. His artificial system had the effect, however, of focusing attention on the taxonomic value of floral structures, and made a profound impression on the botanists of his time. His "Species Planta-

rum" (1753), describing all species known at that time, and his "Genera Plantarum" (5th ed., 1754), similarly describing the genera, stand today as the greatest of botanical classics. These works, with his successful promulgation of the binomial system used, but not established, by Bauhin, and his clear-cut conception of species have made his name immortal.

A. L. de Jussieu.—It is generally conceded that the French botanist, Jussieu, was the founder of the present system of taxonomy, though he took freely from the work of his predecessors. While familiar with Cæsalpini's work, he made but limited use of it. He divided the plant kingdom into fifteen classes, fourteen of them seed plants. These in turn were divided into orders, some of which were roughly comparable to our families. His main subdivisions, as published in 1789, are as follows:

- I. ACOTYLEDONES. Plants without cotyledons: Fungi, Ferns, Mosses, Algae, Naiades (CLASS I)
- II. MONOCOTYLEDONES. Plants with one cotyledon:
 - 1. Stamens hypogynous (CLASS II)
 - 2. Stamens perigynous (CLASS III)
 - 3. Stamens epigynous (CLASS IV)
- III. DICOTYLEDONES. Plants with two cotyledons:
 - 1. Apetalae {
 - Stamens epigynous (CLASS V)
 - Stamens perigynous (CLASS VI)
 - Stamens hypogynous (CLASS VII)
 - Corolla hypogynous (CLASS VIII)
 - 2. Monopetalae {
 - Corolla perigynous (CLASS IX)
 - Corolla epigynous {
 - Anthers connate (CLASS X)
 - Anthers free (CLASS XI)
 - 3. Polypetalae {
 - Stamens epigynous (CLASS XII)
 - Stamens hypogynous (CLASS XIII)
 - Stamens perigynous (CLASS XIV)
 - 4. Dielines irregulares, male and female flowers on different plants, corolla generally absent (CLASS XV)

It will be seen that Jussieu abandoned the primary division into woody *vs.* herbaceous stems, gave major consideration to the cotyledons, and made prominent use of petals and stamens. His system lacks modern conceptions in characters of vascular bundles, floral axes, petals, and carpels, but it has served as a basis on which by addition and correction the best systems have been built.

About this time several important morphological discoveries were made that became serviceable in the classification of plants. Notable among these were Robert Brown's studies on seeds,

including the nature of the endosperm and the lack of carpellate coverings for the ovules in the gymnosperms; Endlicher's anatomical studies, showing the manner of growth in stems and distinctions between stem and root; Lindley's investigations of the vascular bundles in stems and leaves; and Hofmeister's embryological studies, revealing among other things the alternation of generations. Hofmeister evidently realized that the alternation of generations established a natural connection between the Bryophyta, Pteridophyta, and Spermatophyta even though Darwin's "Origin of Species" had not yet been published.

Fortified by these additional discoveries, A. P. de Candolle, Bentham and Hooker, Alexander Braun, A. W. Eichler, and others made considerable improvements on Jussieu's classification.

EVOLUTIONARY SYSTEMS OF TAXONOMY

In the midst of steady progress on the improvement of systems purely and blindly morphological, the conceptions of species and other categories and the ideals of classification were profoundly modified by the introduction of the doctrine of evolution.

Charles Darwin.—Probably the most epoch-making event in the entire history of biological science was the discovery of the principle of evolution. That Darwin was not the first to get an inkling of this principle is well known, but with Wallace he seems to have been the first to comprehend its sweeping significance ("Origin of Species," 1859). After the first wave of excitement was over, systematists quite generally accepted the doctrine and began to revise their systems to fit the new principle of phylogenetic relationships. Fortunately much that had already been done was usable, for all but the morphological systems had been pretty much eliminated, and morphology has proven the best single criterion of phylogeny.

Bentham and Hooker.—These two great English systematists, contemporaries of Darwin, worked out in far greater detail than any of their predecessors a system of classification of the Spermatophyta that for some thirty years dominated the botanical world, and has been modified rather than revolutionized to make the systems in use today.

In their "Genera Plantarum" (1862-1883) they made a rather complete series of categories giving dicotyledons, gymnosperms and monocotyledons equal rank, equivalent to classes,

with the gymnosperms between the other two. The dicotyledons were divided into three subclasses, the further sequence of categories being series, cohort, order, genus, and species. The cohort was practically equivalent to our order and the order to our family. There were altogether two hundred orders (families) beginning with Ranunculaceae and ending with Gramineae, Compositae being near the middle (Number 88).

Julius von Sachs.—Until nearly the close of the nineteenth century, little progress had been made with the classification of the Thallophyta. Following the improvement of the microscope to a point of practical usability, Sachs in 1882 proposed a classification of these lower plants nearly on a par with that of Bentham and Hooker for the spermatophytes though not so detailed.

THALLOPHYTES

Containing chlorophyll.	Not containing chlorophyll.
	Class I. Protophyta
Cyanophyceae.	Schizomycetes
Palmellaceae (in part).	Saccharomycetes.
	Class II. Zygosporeae
	Conjugating cells motile
Pandorineae.	Myxomycetes.
(Hydrodictyae).	
	Conjugating cells stationary
Conjugatae (including Diatomaceae)	Zygomycetes.
	Class III. Oosporeae
Sphaeroplea	
Vaucheria . . . (Coeloblastae) . . .	{ Saprolegnieae.
	{ Peronosporae.
Volvocineae.	
Oedogonieae.	
Fucoideae.	
	Class IV. Carposporeae
Coleochaeteae.	Ascomycetes (including Lichens).
Florideae.	Aecidiomycetes (Uredineae).
Characeae.	Basidiomycetes.

The shrewdness of this great German botanist is shown by this phylogenetic classification in which he attempted to bring out the relationships of the different groups of algae and fungi. While the classification contains some serious mistakes due to the inherent difficulty of the subject and the limited amount of detailed work that had been done on the Thallophyta at that time, the main concept is accepted as correct today.

A. W. Eichler. Based on a considerable study of morphology, made in the light of the doctrine of evolution, Eichler (1883) made a classification of the entire plant kingdom.

A. CRYPTOGRAMAE

I. Division: Thallophyta

I. CLASS: Algae (5 groups)

II. CLASS: Fungi (3 groups, including lichens)

II. Division: Bryophyta

I. Group: Hepaticae

II. Group: Musci

III. Division: Pteridophyta

I. CLASS: Equisetineae

II. CLASS: Lycopodineae

III. CLASS: Filicineae

B. PHANEROGAMAE

I. Division: Gymnospermae

II. Division: Angiospermae

I. CLASS: Monocotyleae (7 orders)

II. CLASS: Dicotyleae

I. SUBCLASS: Choripetalae (21 orders beginning with Amentaceae)

II. SUBCLASS: Sympetalae (9 orders)

Engler and Prantl.—Nearly half a century ago the first volumes of an extensive work by two German botanists, Engler and Prantl, were published (1887-1909). This treatise, "Die Natürlichhen Pflanzenfamilien," covers the entire plant kingdom. While the authors named did much of the work on the flowering plants, many sections throughout the plant kingdom were assigned to other specialists. The Engler and Prantl system is a development of that of Eichler. Its usefulness is increased by the publication of Engler and Gilg's "Syllabus der Pflanzenfamilien" (10th ed. 1924), and both are expressions of what is commonly known as the Englerian system. In this system the seed-bearing plants (Spermatophyta) are designated as Embryophyta siphonogama and are further subdivided as follows:

EMBRYOPHYTA SIPHONOGAMA

I. Subdivision: Gymnospermae

1. CLASS: Cycadofilicales

2. CLASS: Cycadales

3. CLASS: Bennettitales

4. CLASS: Ginkgoales

5. CLASS: Coniferae

6. CLASS: Cordaitales

7. CLASS: Gnetales

II. Subdivision: Angiospermae

1. CLASS: Monocotyledonae (11 orders)

2. CLASS: Dicotyledonae

SUBCLASS Archichlamideae (Choripetalae and Apetalae) (30 orders)

SUBCLASS Metachlamydeae (Sympetalae): (11 orders)

The numerous orders are further subdivided into families and genera.

In this system the monocotyledons are placed between the gymnosperms and the dicotyledons, and the woody plants with unisexual apetalous flowers borne in aments (willows, walnuts, oaks, etc., often called Amentiferae) are treated as among the most primitive dicotyledons. This arrangement is, by many, considered erroneous (see p. 59).

Considering this work as a whole, its value lies in its broad treatment of the entire plant kingdom, its excellent illustrations, and its phylogenetic arrangement of many groups. Being prepared by many authors, it is not surprising that it lacks somewhat in uniformity of treatment. Also in some groups, especially among the lower plants, phylogeny has been sacrificed for the convenience obtained by artificial grouping. This system now dominates the field of systematic botany though not to the exclusion of all others.

Richard Wettstein.—In 1901, Richard Wettstein published the first edition of his "Handbuch der Systematischen Botanik." In the third edition (1924), a book of a thousand pages covers the entire plant kingdom. It has the merit of placing the dicotyledons before the monocotyledons, but gives the amentiferous woody plants (that is, willows, etc.) a position at the beginning of the dicotyledons. The lilies, however, are regarded as more primitive than the grasses, which is in accord with present-day belief in this country.

Recent Developments.—Within the last few years three new, avowedly phylogenetic, systems of taxonomy have been proposed. These have not yet come into general use but are worthy of the most careful study. They will be discussed in the next chapter.

Competition of Systems.—It is regrettable that the systematic botanists of today are not in complete accord on taxonomic usage. There are several systems in use at the present time, agreeing in most particulars but differing in others. Some of them cover the

entire plant kingdom, while others deal only with limited groups, such as the bacteria, the fungi, and the higher plants.

There are at least five reasons for existing differences in taxonomic usage.

1. Often phylogenetic relationships are difficult to determine, the existing evidences being very meager. Under these circumstances the superficial mind may reach a very definite conclusion on evidence that is far from proof; the keen progressive mind may tentatively accept the evidence and make use of it until new evidence is found; while the slow or conservative mind will not use it at all. Then, again, certain lines of evidence may point to one relationship while other lines point to another. Under these circumstances the progressives may be divided into two groups.

2. Even though the evidences conclusively establish certain relationships the resulting classification may not be used because there is an artificial grouping that is more convenient. Let us suppose, for example, that the Zygomycetes, the Oomycetes, the Ascomycetes, and the Basidiomycetes were known to have originated at different times from as many different groups of algae, and that the exact lines of descent were established. Even under these circumstances there is no doubt that some botanists would still treat the algae as one group, and the fungi as another.

3. Some confusion exists with regard to the names that should be applied to certain well-recognized groups. For example, among the family names we have Gramineae *vs.* Poaceae, Leguminosae *vs.* Papilionaceae *vs.* Fabaceae, Cruciferae *vs.* Brassicaceae, Umbelliferae *vs.* Ammiaceae, and Compositae *vs.* Carduaceae. Some of these are strict synonyms, others vary somewhat in their generic inclusions. There are two principles (sometimes conflicting) that determine which synonym should be used. One is that a name of almost universal acceptance should not be replaced by an obscure one. The other is that the first valid name used for a category should never be replaced by another. Because some follow one of these principles and others follow the other, we have inevitable disagreement.

4. As categories are not hard and fast entities, but only man-made devices for dealing with plants collectively, it is natural that some systematists would give a higher rating than others to certain groups. By some authorities Convolvulariaceae and Melanthaceae should be considered as families. By others, they are

tribes of Liliaceae. Numerous other examples could be cited, and this is, in fact, one of the greatest sources of controversy.

5. When a botanist has committed himself to a system of classification to the point of publishing it, he is likely to become unreceptive to evidence that would overthrow or greatly alter it. Criticism only makes him defend his ground the more stubbornly, and he loses his attitude of open-mindedness. He and his opponents forthwith lead opposing schools of thought.

For the sake of expediency a teacher may be forced to give his students a system of classification that he does not consider the best from the standpoint of phylogeny, because the available manuals and the general practice of the region make such a course necessary to avoid hopeless confusion. It is thus probable that the Engler and Prantl system is followed by many who do not believe in its entire correctness.

PRESENT TENDENCIES

We have reached a stage where the most progressive systematists are content with nothing short of phylogenetic arrangements for all groups of plants, although some feel that so complete an accomplishment can never be realized. Any other plan is looked upon as artificial and temporary, or merely an unscientific convenience—an expedient for some special purpose. In certain parts of the plant kingdom, the relationships are pretty well understood in their larger features. Some excellent work has already been published on the detailed arrangement of some of the small groups—certain families, genera, etc. The phylogeny of each genus needs to be studied not only for its own sake but in the hope of getting more light on the relationships of some of the perplexing groups.

Evidence for these phylogenetic arrangements is being developed by researches in paleobotany, ecology, and genetics, as well as in comparative morphology and physiology. The foundations are well laid in these fields, and good progress can be expected.

CHAPTER VI

PHYLOGENY OF SPERMATOPHYTES

Probably the most interesting aspect of systematic botany is the determination of phylogenetic relationships. They present a scientific record of the products of evolution modified by geological and meteorological agencies. Phylogeny is, however, a most difficult subject, for many of the evidences have been effaced. Some of the difficulties have been discussed in Chap. IV. Had there been a written record of all the forms of life on the earth from the beginning to the present time, the phylogeny of any group could have been derived by sufficient reading, but in the absence of such a record we have to resort to more or less indirect evidences.

PHYLOGENETIC EVIDENCES

In all studies of phylogeny the origin of groups and individuals by evolution is assumed as axiomatic, for if there had been an independent creation of each species there would have been no relationships between them. Accepting this doctrine then, our problem is to trace the relationship of existing individuals and groups back through their ancestry, most of which has long since disappeared, leaving only a few scattered fossils and other traces.

Our present knowledge of phylogeny in plants is based chiefly on two lines of research, comparative morphology and paleobotany. These are now being checked by a third method, that of serum diagnosis.

Comparative Morphology.—The close similarity of certain plants to each other appealed to the early botanists long before the conception of evolution took form. They were, therefore, fairly well prepared for this new idea and set diligently about applying their knowledge of morphology to its interpretation. A few laws gradually took form to aid them, principally (1) that life has usually advanced from the simple to the complex (progressive development) but has sometimes been simplified by degeneration of parts (regressive development); (2) that the

simpler forms of life now existing are more like their ancestors than the complex ones (though not exactly the same); (3) Von Bayer's "law of recapitulation," that ontogeny is a brief recapitulation of phylogeny; (4) Dolle's "law of irreversibility in evolution," that a product of evolution never goes back to an ancestral condition; and (5) that homologous rather than analogous structures determine relationship.

Difficulties.—Throughout the Christian era up to the twentieth century there was an accumulation of morphological data far beyond the ability of botanists to interpret. Progress was made to the point of placing many of our plants in more or less well-defined species, genera, and families. Some crude attempts also were made at classes and divisions, resulting in such groups as thallophytes, fungi, and seed plants, quite different from the carefully constructed phyla which some have since proposed. For the most part, classification prior to the twentieth century took this form: that certain genera were believed to constitute a certain family (often called an order), certain families to constitute a certain class, etc., but how the smaller groups should be arranged within the larger was undetermined.

One of the difficulties in using the accumulated mass of morphological data for phylogenetic purposes was lack of knowledge of major and minor characters (see Chap. III), and there is still some disagreement in this field. For example, the distinction between woody and herbaceous plants was given great prominence up to the middle of the eighteenth century, then relegated to a minor position, but in 1926 was revived again by J. Hutchinson¹ in a more scientific form, based on anatomy and histology as well as on external form and general texture. Its relative importance is again a matter of controversy.

Another difficulty lay in determining which of two forms of an organ was the more primitive and which the more modern; for example, separate *vs.* united petals, evergreen *vs.* deciduous leaves, and one *vs.* two cotyledons. On this subject a summary of our present beliefs will be given later (p. 52).

Paleobotany.—Morphology of existing forms of plant life gives incomplete evidence of phylogeny because of the many ancestral forms and connecting links that have long since disappeared. Some of these have been preserved as deposits and recognizable fossils.

¹ "The Families of Flowering Plants," Macmillan & Co. Ltd., London, 1926.

It is believed that the first life began in the sea, which at that time covered all the land and was not so salty as at present. Probably the first forms were so delicate and so scattered that they left no remains that can now be detected. Later the more abundant and substantial forms left deposits of graphite and carbonates, but the cellular structure was quite obliterated. Still later, plants and animals with more solid portions, skeletons, heavy cell walls, etc., dying in localities favorable to their preservation, became covered with earth and a few of them have been recovered as fossils. Doubtless many more are still hidden.

Some of these fossils are merely impressions of the plant part on plastic material that later hardened into rock while the plant itself quite disappeared. Others consist of casts of plant parts replaced bodily or bit by bit with mineral. The slow molecular replacement has produced the best fossils, for in them even the cellular structure is often preserved, sometimes quite faithfully.

The great value of these fossils lies in their chronological history of ancestral forms, "missing links" in evolution, and in their record of evolutionary morphology—the sequence in the development of organs. Most fossils represent extinct species that are, nevertheless, named and classified. Others correspond to species that still exist practically unchanged. In numerous cases fossil records have confirmed or corrected beliefs based on morphology as to the relative antiquity of existing groups, thus showing the trend of evolution. Through the researches of historical geology the strata of the earth's crust have been classified, the method of their formation determined, and with some approximation their ages have been estimated (see frontispiece). Through a combined study of geology and paleontology the climates on the earth at the different periods are known to some extent, and the effects of these climates on the forms of life existing at those times (see p. 9). It is believed that the different phyla of plants and animals originated during profound and disastrous climatic and geological changes that exterminated many species. *Vicissitude begets hardy races.*

Unfortunately, the paleontological records are very fragmentary. While they have yielded much of value and have modified and supplemented somewhat our interpretations of present-day morphology, they have left much unsaid. The softer plants, such as green algae and liverworts, usually failed to leave a recognizable impression, and even most woody plants decayed

and disappeared entirely except under the most favorable conditions for preservation, such as burial by mud. We do not even

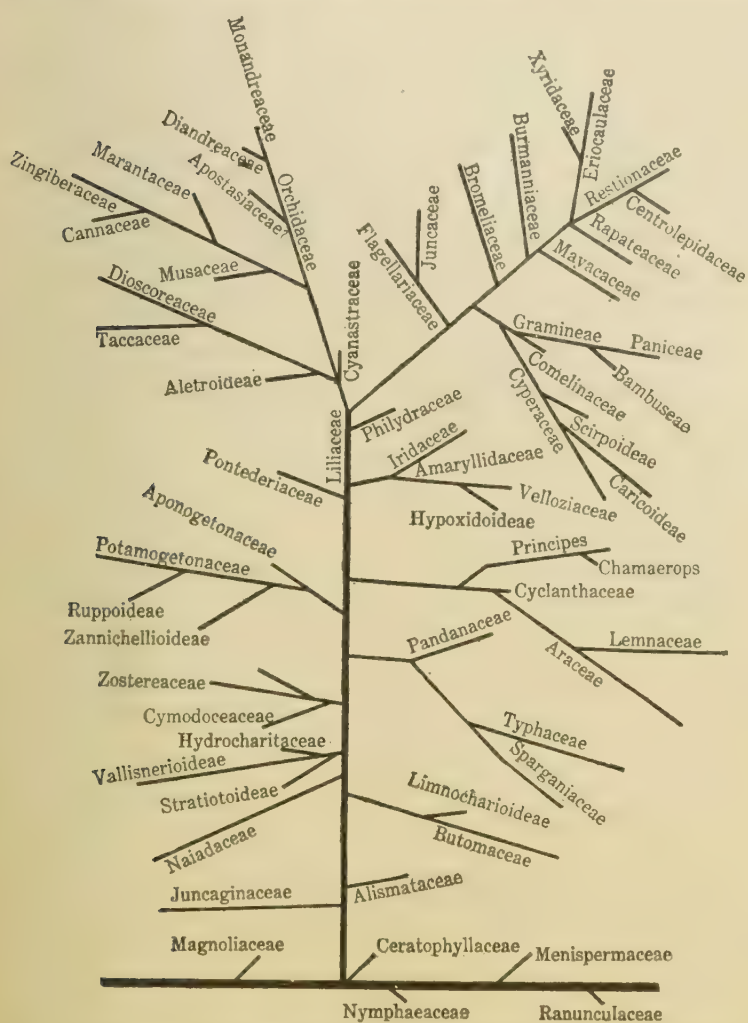


FIG. 1.—Phylogenetic arrangement of the monocotyledons as indicated by serum diagnosis. (Redrawn after Ankermann.)

have a record of the evolution of flowers from the ancestral sporophylls; for although both sporophylls and flowers have been fossilized, transitional forms are lacking. Much is hoped for in

the future, for in all likelihood man will continue to find and interpret fossils for many centuries.

Serum Diagnosis.—The most important physiological or chemical indicator thus far developed to show phylogenetic relationships is the serum diagnosis of Carl Mez, of the University of Koenigsberg, and his associates and students. A properly extracted protein from a plant is mixed with serum either in an animal or *in vitro* and after a suitable length of time a similar protein extract from another plant to be tested for relationship with the first is added. The formation of a precipitate indicates relationship, the strength of the relationship being determined by the abundance and character of the clouding and the dilution at which the serum and protein will form the precipitate. A remarkable phylogenetic tree has been constructed on the results of these reactions, one branch of which is shown in Fig. 1. The relationships thus indicated correspond as well with morphological conclusions as the different morphological conclusions correspond with each other, and it is noteworthy that the phylogenetic lines form a branching system not reticulate, and thus conform to rule 1 of the principles below. The Mez or Koenigsberg serum diagnosis must be looked upon as a most valuable supplement to morphological studies for the determination of relationship, although the work is still new and need much verification.

MORPHOLOGICAL INDICATORS OF PHYLOGENY

To facilitate piecing together our morphological data into a phylogenetic system of classification we need to know many details of the trend of evolution. This knowledge has been derived slowly but now there is rather uniform agreement on the following principles.¹

1. Plant relationships are up and down genetic lines, and these must constitute the framework of phylogenetic taxonomy. This will naturally form a branching but not reticulate structure.

2. Some evolutionary processes are progressive while others are regressive.

¹ Most of these rules were stated in slightly different form by Charles E. Bessey, The phylogenetic taxonomy of flowering plants, *Ann. Mo. Bot. Gard.*, 2: 109-164, 1915. A few others have been added by Alfred Gundersen, Evolution in flowering plants, *Brooklyn Bot. Gard. Leaflets*, Ser. XI, No. 9, 1923, and by J. Hutchinson, "The Families of Flowering Plants," pp. 6 and 7, Macmillan & Co. Ltd., 1926.

3. Evolution does not necessarily involve all organs of the plant at one time or in the same direction. One organ may be advancing while another is stationary or retrograding.

4. Evolution has generally been consistent, and when a particular progression or regression has set in, it is persisted in to the end of the phylum.

5. In any phylum the chlorophyll-bearing plants precede the chlorophyllless ones.¹ Saprophytes are derived from independent forms, and parasites usually from saprophytes among the lower plants, and from independent forms among the flowering plants.

6. Usually structures with many similar parts are more primitive, and those with fewer and dissimilar parts are more advanced.

7. Among the seed plants the stem structure with collateral bundles arranged in a cylinder is more primitive than that with scattered bundles.

8. In most groups of seed plants woody members have preceded the herbaceous ones.

9. In most groups of seed plants erect members have preceded the vines.

10. Perennials are more primitive than biennials and biennials are usually more primitive than annuals.

11. Scalariform vessels are more primitive than vessels with round pits.

12. The spiral arrangement on the stem and of the floral leaves precedes that of the opposite whorled type.²

¹Exception should be made of the most ancient primitive life which probably possessed no chlorophyll. Many believe that the bacteria and the blue-green algae had a common ancestry lacking chlorophyll.

²This is the statement given by Hutchinson. Bessey had earlier stated, "Historically the arrangement of the leaves in pairs on the stem is held to have preceded the spiral arrangement in which the leaves are solitary at the nodes." This is reasoned from the fact that in dicotyledonous plants the first leaves (cotyledons) of the embryo are formed two at a node while in the monocotyledonous plants there is but one at a node.

As a matter of fact many families in both monocotyledons and dicotyledons contain some species with one arrangement of the foliage leaves and other species with the other arrangement, sometimes both in the same genus. Also some individual plants have one arrangement of the lower leaves and the other arrangement above. It is evident, therefore, that the change from either arrangement to the other is an easy one. For this reason the principle must be applied with discretion, although it has value in a study of floral organs.

13. Simple leaves are more primitive than compound leaves.
14. Historically, leaves were first persistent (evergreen) and later deciduous.
15. Among the seed plants the netted venation of leaves is more primitive than the parallel venation.
16. The many-parted flower is the more primitive, the type with few parts being derived from it, and the change is accompanied by a progressive sterilization of sporophylls.
17. A condition in which the perianth consists of like segments is more primitive than one in which sepals and petals are unlike each other.
18. Flowers with petals preceded apetalous ones, the latter being derived by reduction.
19. Polypetalous flowers are more primitive than gamopetalous ones, the latter being derived from the former by symphysis.
20. Regular flowers preceded irregular ones.
21. Spirally imbricate floral parts are more primitive than those that are whorled and valvate.
22. Hypogyny is the primitive structure and from it perigyny and epigyny have been derived.
23. Numerous carpels represent a more primitive condition than few carpels.
24. Separate carpels represent a more primitive condition than united carpels.
25. Axile placentation preceded parietal and central placentation of ovaries.
26. The presence of numerous stamens indicates a more primitive condition than that of few stamens.
27. Separate stamens preceded united stamens.
28. Evolution in angiosperms is believed to have proceeded from seeds with two seed coats to those with only one.
29. The primitive seed contains endosperm and a small embryo, the advanced type has little or no endosperm with the food stored in a large embryo.
30. A straight embryo is usually more primitive than a curved one.
31. The solitary flower is more primitive than the inflorescence.
32. Bisexual flowers preceded unisexual flowers, which were derived from them by reduction.
33. The monoecious condition is earlier than the dioecious.

34. Simple and aggregate fruits preceded multiple fruits.

35. The same evolutionary phenomena have often been repeated as separate occurrences in different parts of the plant kingdom, *e.g.*, loss of chlorophyll, loss of petals, stamens, and carpels, acquisition of fleshy texture in fruits and of various types of thorns, change from simple to compound leaves, from erect to prostrate habit, and from hypogynous to perigynous or epigynous insertion of floral parts, and lateral union (symplysis) of petals, stamens, and carpels.

36. In determining the closeness of relationship between two families or other groups it is usually best to compare with each other the more primitive, or basal, members of each group, rather than those that are simplified by reduction or those that are most highly specialized.

Some of these rules, *e.g.*, 2, 3, 29, 31, and 35 are statements of established facts, while others, *e.g.*, 6, 8, 10, 14, and 15 must be looked upon as general principles with probable exceptions. Most phylogenetic systems of taxonomy are built on these principles, and they should serve as guides to every student in the analysis of such systems.

RECENT PHYLOGENETIC CONCEPTIONS

The principles just enumerated have been used by American and European botanists as a basis for systems of classification that show improvement over that of Engler and Prantl, reviewed in the last chapter.

The Bessey System.—For more than a quarter of a century the University of Nebraska was the center of activities that did much to clarify our knowledge of phylogeny. These were led by Dr. Charles E. Bessey and culminated¹ in what is known as the Bessey system, which was fully set forth in 1915 in the article referred to on page 52 and in "Essentials of College Botany" by C. E. Bessey and his son, Ernst A. Bessey. Their graphic scheme of the angiosperms is given in Fig. 2, page 56. This system is based on the principles set forth in this chapter, and it possesses the double advantage of being both convenient and representative of a phylogenetic conception. It deserves to

¹ The main skeleton of the Bessey system was published much earlier (*Bot. Gaz.*, **24**: 145-178, 1897), but was revised from time to time with respect to certain details.

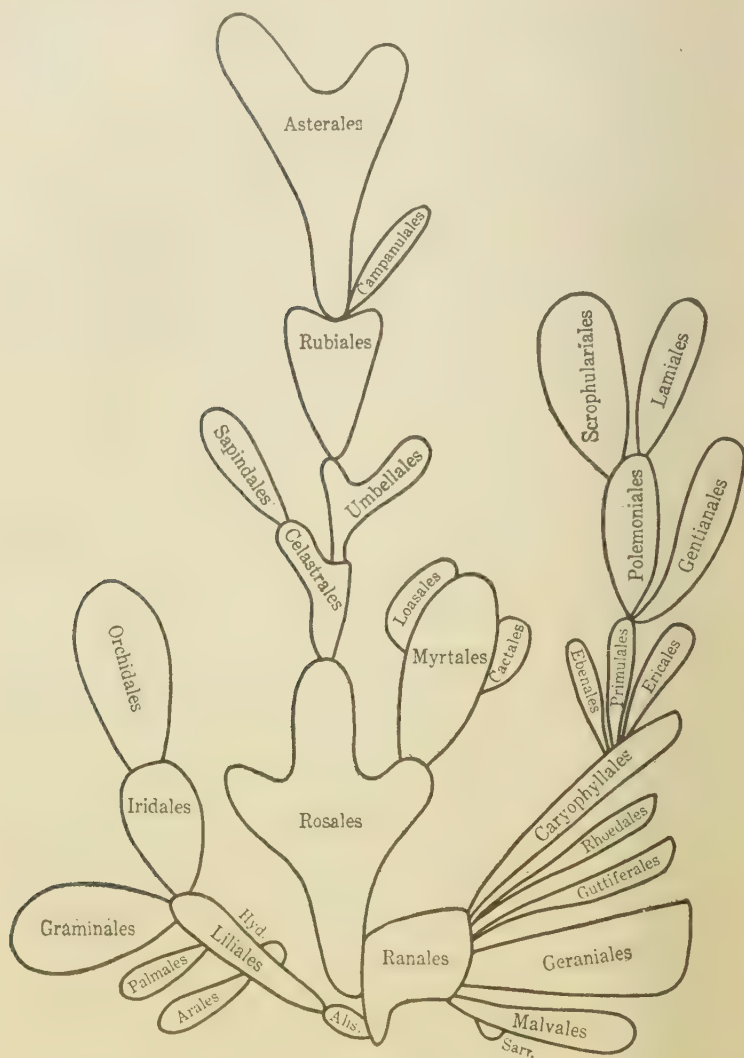


FIG. 2.—Chart showing Bessey's conception of the relationships of the orders of angiosperms. Relationship is indicated by position. The areas are approximately proportional to the number of species in the orders. (Redrawn after Bessey.)

be more extensively used, even though further research may result in a gradual improvement of certain parts.

The Hallier System.—In 1905, Hans Hallier¹ took issue with “Die Natürlichen Pflanzenfamilien” (1) in giving a different origin to different members of the angiosperms, (2) in regarding the “Amentaceae” as primitive types, and (3) in the derivation of the monocotyledons. He proposed tentatively a phylogenetic system correcting these faults. In condensed form it is as follows:

A. SPOROPHYTES

- I. Filicales
- II. Lycopodiales
 - a. Isosporae
 - b. Heterosporae
- III. Equisetales

B. SPERMATOPHYTES

- a. Gymnosperms (excluding Gnetaceae).
 - 1. Cycadaceae. 2. Bennettitaceae. 3. Coniferae
- b. Angiosperms
 - (A) Dicotyledons
 - I. Polycarpicae (Magnolineae, etc.)
 - II. Ranales (Nymphaeaceae, Ranunculaceae, etc.)
 - III. Rhoeadales (Capparidaceae, Cruciferae, etc.)
 - IV. Piperales (Piperaceae, etc.)
 - V. Malvales (Malvaceae, Urticaceae, etc.)
 - VI. Ebenales (Convolvulaceae, etc.)
 - VII. Geraniales (Geraniaceae, etc.)
 - VIII. Myrtiflorae (Myrtaceae, etc.)
 - IX. Rosales (Rosaceae, Leguminosae, etc.)
 - X. Ericales (Ericaceae, Primulaceae, etc.)
 - XI. Sarraceniales (Sarraceniaceae, etc.)
 - XII. Santalales (Santalaceae, Gnetaceae, etc.)
 - XIII. Umbelliflorae (Cornaceae, Umbelliferae, etc.)
 - XIV. Amentiflorae (Salicaceae, Juglandaceae, etc.)
 - XV. Passiflorales (Onagraceae, Campanulaceae, Compositae, etc.)
 - XVI. Centrospermae (Portulacaceae, Polygonaceae, etc.)
 - XVII. Caprifoliales (Caprifoliaceae, etc.)
 - XVIII. Tubiflorae (Labiales, Solanaceae, etc.)
 - (B) Monocotyledons (descendants of Nymphaeaceae)
- XIX. Helobiae (Alismaceae, Juncaginaceae)

(The work on the Monocotyledons unfinished)

It will be noted that the Hallier system was developed simultaneously with that of Bessey and has many features in common with it.

¹ Provisional system of the natural (phylogenetic) system of flowering plants, *The New Phytologist*, 4: 151-162, 1905.

Lotsy¹ in an unfinished system, the last volume of which appeared in 1911, follows Hallier in many respects.

The Clements System.—In 1914 appeared "Rocky Mountain Flowers" by F. E. Clements and Edith S. Clements. This illustrated book gives in semi-popular form a classification of the flora of the central Rocky Mountain region. The plan is a modification of that of Bessey, but it has two additional features. In the introduction is a "Flower Chart," a phylogenetic diagram and key combined. In this diagram the lines of phylogeny are shown and across them run other lines that indicate boundaries between primitive and advanced floral types, *i.e.*, union of corolla, regularity of corolla, attachment of corolla, and union of carpels. Also in the chart the families are designated by formulae indicating the number and arrangement of floral parts characteristic of them, thus giving a concise approximate picture of the family. The book is non-technical in character and limited in its scope to the angiosperms of a restricted region.

The Hutchinson System.—The most recent effort in this field is "The Families of Flowering Plants," by J. Hutchinson of the Royal Botanic Gardens, Kew, England, the first volume of which, on the dicotyledons, appeared in 1926. In its underlying principles it is much more like the Bessey system than the Engler system. Its main features are as follows:

1. It renews the ancient emphasis on the distinction between arborescent and herbaceous habit, but this character is here used in conjunction with other qualities. As a result of giving major emphasis to this distinction two primitive or basal orders are recognized, the Magnoliales, mostly woody and giving rise to other orders that are mostly woody, and the Ranales, mostly herbaceous and giving rise to other orders that are mostly herbaceous.

2. Partly as a result of the distinction just mentioned in the first feature, certain groups containing both woody and herbaceous members are made to appear polyphyletic; that is, some members arising from one ancestry and others from a different one. Such a position is given to the "Apetalae," the Urticales, the Umbelliflorae, and the Asterales, for example. Plants with apetalous flowers of course have no status as a phylogenetic group but the status of the others is debatable. Whenever it can be established that different members of a group have

¹ Lotsy, J. P., "Botanische Stammesgeschichte," Vols. I, II, and III.

separate ancestry, the group should be divided and the parts given distinct names if the interests of phylogenetic taxonomy are to be served. Otherwise a reticulate arrangement is formed.

3. There is a strong tendency to subdivide some of the older orders and families, not because of their size but because of their apparently heterogeneous nature.

4. The monocotyledons (to be treated in the second volume) are regarded as offshoots of the dicotyledons, perhaps at more than one point, *i.e.*, they may be polyphyletic.

Even though some may doubt the wisdom of maintaining his distinctions between the various types of woody and herbaceous plants all will agree that the system shows an advanced step in phylogenetic conception.

Summarizing the work of the last half-century we find two different tendencies: (1) The work of Eichler and Engler, placing monocotyledons before dicotyledons, deriving dicotyledons from gymnosperms with unisexual strobili, and giving Amentiferae a primitive position among dicotyledons. (2) The work of Bessey, Hallier, Lotsy, Clements, Shaffner, Hutchinson, and Mez, giving monocotyledons an early derivation from the dicotyledons,¹ deriving dicotyledons from gymnosperms with bisexual strobili, regarding Amentiferae as a heterogeneous group, simple by reduction, and making Ranales, in the older sense of the term, the basal group of the dicotyledons. The botanists of this group, while agreeing on these large issues, hold different views on the relationships of various orders and families, and, it should be added, are quite in harmony with Engler on very many points.

Need for Revision of Manuals.—Differences of opinion concerning phylogenetic arrangement are natural and inevitable in the present state of our knowledge, and a shifting of ground must be expected as long as new evidence is forthcoming. It would be absurd for a botanical congress to seek to establish the facts by passing resolutions in favor of one system or another. Facts cannot be altered by proclamation. The writers of manuals and general treatises, however, can well lead the way by adopting the newer conceptions whenever they appear to be as well established as are those discussed in the second tendency of the preceding paragraph.

¹ Schaffner believes the two to have been derived from a common ancestor.

CHAPTER VII

NOMENCLATURE

In a general way the term nomenclature is used to cover any system of names, or indeed the names in use whether or not they follow a system. Using the same names, plants might be classified in various ways, or they might not be classified at all.

Relation of Nomenclature to Taxonomy.—Conceivably a system of nomenclature might exist that would be independent of classification. Such a nomenclature would supply a name to each *individual*. In botany this would be quite impossible. As soon, however, as we assert that certain individuals are essentially alike, and offer a specific name to the group, we are linking nomenclature with taxonomy; for such a grouping is in itself a recognition of relationship. The binomial system carries us still further into taxonomy for in it the name not only designates a group of like individuals, the species, but it indicates a larger group, the genus, where related species may be found. In systematic botany, then, nomenclature and taxonomy are inseparable.

Names Usually Descriptive.—It is natural that the name given to a plant shall, in a measure, describe it or something connected with it. The name may refer to its appearance, as buttercup; to its habitat, as watercress; to its properties, as dogbane; or to some person that has been associated with it, as Johnson grass. Such terms have a meaning only to people familiar with that language, and indeed in the evolution of a language the meanings of terms are often forgotten. Dandelion, rose, mullein, yarrow, and huckleberry are doubtfully descriptive today.

COMMON NAMES

Probably all nations and tribes have given names to plants, each in its own language. Such terms are learned in childhood and handed down from generation to generation. They are fairly definite if the plants have no closely similar relatives, as

cow parsnip, white sweet clover, basswood, and sassafras, but are loosely applied among plants having many similar kinds in a group, as the grasses, willows, huckleberries, and goldenrods. A common name may or may not represent a species in the botanical sense. Sometimes it includes everything within a genus, and it may be the generic name as *Iris*, with or without a qualifying adjective as *Persian Iris*. In any event the same name is applied to all plants supposed to be the same *kind*. No attempt is made to name each *individual* plant except in case of unusual specimens—mostly trees of sentimental value.

The Value of Common Names.—There is a tendency for systematists, especially beginners, to hold common names in contempt. This attitude is natural enough but may be overdone. The common name is generally somewhat descriptive to those using it, and is easily learned and remembered, because of its familiar sound, even though long, as *Jack-in-the-pulpit*, *dog-tooth violet*, and *bachelor's button*. In the majority of cases, the approximate accuracy of the name is sufficient for the purposes of the person using it, as *pine* or *elm*. If a little more definiteness is desired an adjective may be added as *yellow pine* or *slippery elm*. It is safe to say that as a rule the common name is quite satisfactory to the non-technical person, and more satisfactory than the so-called scientific or botanical name would be. The common name may be monomial, binomial, trinomial, or polynomial.

The Weaknesses of Common Names.—There are three principal defects in common names: (1) they may be quite indefinite, (2) they are restricted to the people of one language, (3) they are not regulated by any constituted authority.

We now hold that unless a common name is strictly synonymous with the specific name, or in some cases a varietal name, it is too vague for scientific usage. *Buttercup*, *daisy*, and *goldenrod* are familiar examples. In a large country, a plant may be called by different names as *pennycress*, *fanweed*, and *stinkweed*. On the other hand the same name, as *bluebell* or *bunch-grass*, may be applied to several different plants. Such differences in usage are highly confusing, provoke many fruitless controversies, and make the terms wholly unusable for scientific purposes.

When traveling in a foreign country, the local names encountered are even more troublesome than botanical names, for they are just as hard to learn and have the disadvantages found in all

common names, and if one travels or reads extensively he has many sets of names to learn.

There is no court of last appeal to settle controversies concerning the accuracy of common names. We have, to be sure, a book entitled "Standardized Plant Names" (see p. 109), which is a move in the right direction and valuable as far as it goes; but it is largely restricted to the cultivated plants offered for sale by nurseries and seed houses. Most of the lists of common names of wild plants make a free use of synonyms, and if any community wishes to adopt a new name for a plant, as has been done hundreds of times, there is no authority to stop it and the confusion is increased.

BOTANICAL OR SCIENTIFIC NAMES

Every science has developed a terminology of its own, a set of technical terms peculiar to the subject matter of that science. In systematic botany these technical names of plants number many thousands and are far in excess of the common names.

Origin and Nature of Botanical Names.—To get a correct conception of scientific names the reader must understand something of their composition. Many of the older names are Greek in origin, but are now used in Latinized form, and the later ones are mostly Latin. Each name should be all one or the other—not mixed. The generic name is the noun—the true name of the kind of plant in question. Usually it is descriptive. The specific name is a qualifying adjective amplifying the generic description and indicating, in most cases, that the individuals making up the genus vary somewhat and fall naturally into several smaller groups. In the first use of specific names often two, three, or more were applied to extend the description; but this practice resulted in such cumbersome names that the binomial system was adopted—a noun with one adjective. Theoretically, then, the genus might be considered the unit of nomenclature, and in some cases primitive peoples have used names corresponding to genera rather than species. It has been found more useful, however, in modern taxonomy to consider the species the unit.

Origin of the Binomial System.—The present binomial system of nomenclature had a long evolutionary development. Cato in his "*De Re Rustica*," written about two centuries B.C., used two names for plants, although he lacked the modern conception of

genera made up of several species. Later, two tendencies came in. One was to translate the descriptive Greek nouns used for genera into Latin, in which language they took the form of two words, *i.e.*, binary generic names. The other was to give a descriptive phrase for the specific name. Both these methods resulted in what have been called polynomials. Brunfels in the middle of the sixteenth century changed many binary generic names to single ones, and Dodonaeus, a few years later, followed for the most part binomial usage similar in principle to that of today. Gaspard Bauhin in his "Pinax," a list of some six thousand plants, written in 1623, used the binomial system even more extensively, though not exclusively.

None of these writers, however, impressed upon the botanical world of their time the desirability of abandoning all practice other than binomial, and works continued to appear having mixed usage—monomial, binomial, trinomial, and polynomial. They did, probably, influence Linnaeus to more fruitful efforts through philosophical discussions of the subject in his "Philosophia Botanica" (1751), and to a consistent practice of one generic and one specific name in his "Species Plantarum" (1753).

Advantages of Botanical Names.—Two great advantages are commonly claimed for botanical or "scientific" names: (1) that they are the same among scientific people the world over, (2) that they are uniformly binomial. We shall see presently that while these two qualities are usually found, there are some exceptions.

The greatest advantage of the botanical name is its exactness. If our present system of nomenclature were perfected, each kind of plant would be called by one binomial name only (aside from its common names), and that name would mean the same species to all botanists. Even now this situation exists with regard to the majority of plants, but there are some that are still in controversy and are called by two or more synonymous names, some of which may be trinomial.

It is also claimed that the botanical name has the special advantage of being descriptive of the plant. This claim has little force, however, for most common names are likewise descriptive, and as the majority of botanists today are not skilled in Greek and Latin, they do not appreciate the descriptive value of most of these terms.

A further advantage of the botanical name is that it is governed in some measure by world-wide rules of nomenclature, and many names made in violation of these rules have been discarded.

Disadvantages of Botanical Names.—The usual objection offered to botanical names is that they are so long and hard to learn. In reality the difficulty lies not so much in their length as in their unfamiliar sounds and combinations. *Oxyria digyna* and *Ruellia strepens* are not long names, but most people would think them hard because they are, to them, unfamiliar and meaningless.

Another reason why botanical names will often be unusable to the layman lies in the fact that they require an exact delineation of species; and while some species are clearly defined, with easily recognized characters, others look so much alike that technical skill is required to separate them.

NON-VALID NAMES

Many of the names that have been applied to groups of plants have been found unusable for various reasons. Some of these names have been given by excellent botanists who have unavoidably fallen into error, others have been due to the carelessness or crudeness of poorly trained men whose zeal to propose new names has exceeded their ability to apply them.

Synonyms.—By the rules of botanical nomenclature, given later in this chapter, a plant or group can have but one valid scientific name, and no two groups can have the same name. For various reasons, however, most specific groups have received two or more names. In such cases methods have been devised for determining the one valid name, and all the others are classed as synonyms, or, according to certain usages, the term synonym is applied to both the valid name and the invalid ones. While synonyms are commonest in the designation of species they may also be found among generic and family names.

Typonyms.—"A name is rejected when there is an older valid name based on the same type (typonym)."¹ Typonyms are sometimes called "absolute synonyms" because the older valid name and the newer invalid ones refer unquestionably to the same plant or group.

¹ This quotation and those defining metonym, homonym, and hyponym are taken from the "American Code of Nomenclature" (see pp. 71 and 101).

A few examples will serve to make clear the nature of typonyms. In 1894 G. S. Jenman gave the name *Asplenium Guildingii* to a plant and three years later Hermann Christ, named the same specimen *A. Vincentis*, thereby establishing a typonym. The generic name *Miegia* given by C. H. Persoon in 1805 is a typonymy of *Arundinaria* given by Andre Michaux to the same species in 1803.

Metonyms.—"A name is rejected when there is an older valid name based on another member of the same group (metonym)." Had the two species mentioned in the preceding paragraph been named from different type specimens, *A. Vincentis* might have been called a metonym. Likewise, *Miegia* might have been regarded as a metonym of *Arundinaria* if it had been based on a different species. The generic names *Bromus*, *Chaetochloa*, *Zernia*, *Serrapaleus*, and *Forasaccus* were based on different species. Most authorities consider all these to be the same genus, therefore, *Bromus*, the oldest, is the valid name and the other four are metonyms. *Panicum pilosum* Swartz, *P. distichum* Lam., *P. pilisparsum* Meyer, and *P. trichophorum* Schrad. were named from different specimens, which probably represent the same species. *P. pilosum*, being of the earliest date, should be regarded as the valid name and the rest as metonyms.

It will be noted that personal opinion enters into the determination of metonyms, for in the minds of those who do not consider identical the groups to which the different names are applied no such metonyms exist, each name being valid for its group.

Metonyms and typonyms have arisen in several ways. In early days the seriousness of duplicate names was not appreciated. Botanical names up to the sixteenth century had somewhat the same stability that common names have today. If a botanist happened to know the name by which a plant was designated he generally used that name. If not, or if he did not like the name in use, he proposed another. Furthermore, the name given a plant was not always published with a description of the plant as is the custom now. Since the time of Linnaeus a serious effort has been made to follow the names in use rather than to apply new ones. This is often difficult to do, however. Many names and descriptions have been published in obscure books, journals, and pamphlets, in various languages. Occasionally, also, two names have been published so nearly simultaneously that the first was not distributed to the botanical world

until the second had been entered for publication. Furthermore, some botanists have not been careful to look up established names before proposing new ones.

Sometimes the author of the first name gave the plant an imperfect description and a later worker seeing the same species in a different environment believed he had found a different species, and gave it a new name. In the lower plants, especially the fungi, different stages in a life history have given rise to different names. Thus *Fusicladium dendriticum*, representing the conidial stage of the apple-seab fungus, is a synonym of *Venturia inaequalis*, the ascospore stage of the same fungus. The uniting of two named groups erroneously supposed to be distinct will always result in synonyms.

Homonyms.—“A name is rejected when preoccupied (homonym).” The same name cannot properly be applied to two different groups. If this is done the name is a homonym in every application except the first. In the binomial system the full name of a plant is the genus (noun) with the species (qualifying adjective). Therefore, it is permissible to use the same specific name in different genera as *Quercus alba*, *Melilotus alba*, and *Chenopodium album*. Likewise it is permissible to use the same generic name with different specific names as *Pinus flexilis*, *Pinus ponderosa*, and *Pinus sylvestris*. It is not, however, permissible to use the same generic and specific combination for plants of different species. *Asarum macranthum*, *Phaca villosa*, and *Vitis virginiana* are among the numerous names that have been thus misapplied. Neither is it permissible to use the same generic, family, or order names, for different groups. For example, the generic name *Setaria* has been applied to lichens (1803) and to grasses (1812). In such a case the name is valid for the first group to which it was applied but an invalid homonym in its later application.

Most homonyms have arisen in this way: A botanist studying a species or other group that he believed to be new applied to it a name that seemed descriptive but had already been used, unknown to him. As names are not completely descriptive of plants, but rather suggestive of a conspicuous quality, it is not surprising that the same name should fit two unrelated groups. Indeed, the same name has been appropriately applied to both a group of plants and a group of animals, as *Cereus* for a cactus and a sea anemone and *Hystrix* for a hedgehog and a grass.

It should be understood that a slight difference in the spelling of a word does not necessarily make it a different word. Such a difference may be due to a typographical error, to a contraction, or to the grammatical necessity of making the specific name correspond to the generic name. For example, *Astrocarpus* is a contraction of *Asterocarpus* and *albus*, *aiba*, and *album* are respectively masculine, feminine, and neuter forms of the same adjective, meaning white.

Hyponyms.—"A name is rejected when the natural group to which it applies is undetermined (hyponym)." When a name is first applied to a group, the group should be so described, or illustrated, or referred to preserved plants, that its scope can be determined by other botanists. A name not so connected with its natural group is a hyponym and invalid for the group for which it was intended. It is sometimes a matter of opinion whether or not a name has been sufficiently defined. The description, illustration, or other means of identification may be rather poor so that one botanist will think it usable and another will reject it. The generic name *Aragallus*, though classed as a hyponym by some authorities, is used by others. *Adodendrum* Necker and *Calesian* Adams are generic hyponyms and *Gentiana hybrida* Raf. and *Lechea furfuracea* Raf. are specific hyponyms.

Dividing and Uniting Groups.—When deeper investigation shows the desirability of dividing a species or other group, the original name is retained by the branch that contains the oldest named member, and a new name is proposed for the other branch. For example, the generic name *Prunus* was at one time used for both plums and cherries. Some have thought it desirable to divide the genus, and as *Prunus domestica*, a plum, was the original species on which the genus *Prunus* was based, the plums retained the name *Prunus* and those cherries that were placed in a new genus were given the name *Padus*.

When two or more genera or other groups are found to be identical in composition and to differ only in name they are united under the oldest valid name, and the others become metonyms, as in the case of *Bromus* on page 65.

From the foregoing discussion of invalid names it will be seen that typonyms and metonyms represent two different kinds of synonyms, and furthermore that homonyms and hyponyms result in the formation of synonyms, for these names must be replaced by usable terms leaving them as synonyms.

CITING AUTHORITY FOR NAMES

With so many invalid names in botanical literature it is often difficult to determine valid ones. The confusion is somewhat lessened by giving the name of the author (usually abbreviated) immediately after the binomial. This designation of the author is, in fact, considered a part of the full name of the plant and follows the specific name with no intervening punctuation mark, as *Lilium canadense* L. and *Mertensia virginica* (L.) DC. The correct generic and specific name and authority are usually derived from the array of synonyms as follows. By an examination of the plant it is found that it belongs to a certain genus and that several specific names have been applied to it. In most cases the first specific name under which it was described is the valid one even though it was not originally placed in the correct genus.¹ If the plant was first named correctly as to both genus and species the name of the author follows without parentheses. For example, Linnaeus correctly applied the name *Lilium canadense* L. If, however, a botanist when naming a plant placed it in the wrong genus, the error must later be corrected, in which case it will retain its earliest valid specific name when changed to the proper genus. The name of the one who first gave the specific name (in the wrong genus) will follow in parenthesis and the name of the one who first gave the correct generic and specific combination will come afterward, not in parenthesis. *Mertensia virginica* was first called *Pulmonaria virginica* in 1753 by Linnaeus, and in 1846 DeCandolle showed that it belonged to the genus *Mertensia*, hence the name *Mertensia virginica* (L.) DC. A few other examples will serve to show how specific synonymy is determined.

1. Linnaeus' "Species Plantarum" in 1753 gave the name *Glechoma hederacea* to a plant. In 1834 Bentham named the same species *Nepeta glechoma* and in 1888 Britton, Sterns, and Poggenburg named it *Nepeta hederacea*. Linnaeus was the first to give it a usable specific name, and if he placed it in the correct genus, its name should stand as *Glechoma hederacea* L. and those proposed later should become invalid synonyms.

2. In 1824 Bigelow named a species *Lactuca integrifolia*. This proved to be a homonym, however, for in 1818 Nuttall had applied the same name to a different species. This species of

¹ By agreement botanists do not go back of Linnaeus' "Species Plantarum" (1753) to establish priority in the publication of names.

Nuttall's is now correctly known as *Lactuca pulchella*, and therefore *L. integrifolia* is an invalid synonym for it. Nevertheless, because it was applied to *L. pulchella* before it was applied to Bigelow's species, it cannot be used for the latter, or indeed for any species. For this reason Ellis proposed a new name *L. sagittifolia* for the species that Bigelow had incorrectly named *L. integrifolia*.

3. In 1828 Nuttall[†] called a plant *Nuttallia involucrata*, but did not give it a specific description. This name therefore was a hyponym and invalid. In 1838 Torrey and Gray named the plant *Malva involucrata*. Ten years later Gray decided that the plant belonged to the genus *Callirrhoe*. Its correct name is therefore *Callirrhoe involucrata* (T. & G.) A. Gray.

4. In 1753 Linnaeus' "Species Plantarum" gave the name *Arnica montana* var. *alpina*. In 1799 Olin and Ladin did away with the trinomial by giving the varietal name a specific value, and the plant is now known as *A. alpina* (L.) Olin & Ladin.

EFFORTS TOWARD UNIFORMITY

Realizing the confusion that is produced by the use of invalid names and the uncertainty as to what should constitute validity, botanists have made repeated efforts to reach a common basis. These efforts have taken the form of comprehensive publications, such as Linnaeus' "Genera Plantarum" and "Species Plantarum" and Bentham and Hooker's "Genera Plantarum," and, more recently, international meetings.

International Botanical Congresses.—It is conceivable that representative botanists from all civilized countries might convene to discuss any or all aspects of botanical science, but in fact until very recently nomenclature and limited aspects of taxonomy have received almost exclusive attention.

The first International Botanical Congress met in Paris in 1867. Its work was highly constructive but conservative. It set forth ideals and principles and made rules of nomenclature, most of which were statements of procedures already in use by many prominent botanists, though not by all. Arbitrary and untried regulations were wisely avoided. The following provisions, among others, were adopted: (1) a plant can have but one valid technical name; (2) that name shall be the oldest usable one, beginning with Linnaeus' "Species Plantarum" (1753); (3) two different species or other groups cannot bear the same name; (4)

generic and specific combinations should be followed by the name or names of their authors. The Paris Code, as it has been called, also clarified and to some extent unified the use of categories for taxonomy and threw strong emphasis on the desirability of Latin names.

A second International Botanical Congress met in Geneva in 1892, but made no distinctive contribution.

In 1905, after the Paris Code had been given a thorough trial, the third International Botanical Congress met in Vienna. In general the principles and rules of the Paris Code were readopted but many slight changes in wording were made as a result of experience in applying that code. The Vienna Code made the following notable changes: (1) the use of Linnaeus' "*Species Plantarum*" as a beginning point for priority of names is limited to vascular plants; (2) recognition is given to Linnaeus' "*Genera Plantarum*," fifth edition, published in 1754; (3) names that have been rejected for certain reasons can be applied as new names to other groups; (4) any new name will be invalid unless a Latin description of the group is published with it; (5) a list of "*nomina conservanda*" or names retained although not valid under the rules is authorized. These are mostly generic names that had come into prominent use either before the adoption of the Paris Code or in violation of it. The code was published¹ in French, English, and German.

In 1910 the fourth International Botanical Congress met at Brussels. It legalized different starting points for priority among the non-vascular plants, recognized the value of the "type concept" of American botanists, and made minor improvements in the statement of several of the rules.

American Contributions.—The American botanists working through the botanical section of the American Association for the Advancement of Science have taken a progressive attitude toward unified nomenclature for the last quarter of a century. In 1903, this organization appointed a nomenclature commission which prepared a code for submission to the Vienna Congress. It introduced the "type concept" which is, briefly, that each species shall be based on a type individual, each genus shall be based on a type species, etc. This idea was rejected by the Vienna Congress. Because of this rejection, because of the disbelief of the American representatives in the "*nomina conservanda*," and

¹ See p. 101.

because of the arbitrary requirement of Latin descriptions of new groups, their code was revised and published¹ in 1907 as the American Code. In most respects it is like the International Rules or Vienna Code. Unlike the Vienna Code, however, it provides that "A name is invalidated by an earlier homonym even though the latter may not be valid" (see example 2, p. 68). It has a considerable following in this country at the present time as has also the "Type-basis Code"² presented by the Committee on Nomenclature in 1918, but not formally adopted.

The type-concept embodies a useful principle which is often misunderstood because of the name. Its fundamental purpose is to associate each specific name and description with a definite preserved specimen, each generic name and description with a named species, and each higher category with a definite member of a lower category included under it. The emphasis is on type species and type individuals. In the selection or designation of types, priority is intended to rule wherever possible, *i.e.*, the specimen that was used in defining a species becomes the type of the species, and the species that was used in defining a genus becomes the generic type.

The confusion comes largely through the use of the word "type," which has more than one meaning. It should be understood that the reference here is to a nomenclatural type—a definite entity with which the name is associated to prevent its being merely a detached conception. The type concept is not an effort to select a *typical* member of the group, although, quite naturally, the type is usually somewhat representative.

The strength of the type-concept lies in having a definite entity, a plant or a group of plants, rather than a mere written description, for a guide. Such descriptions are admittedly imperfect in that they express only certain qualities that appeal to the author and leave much unsaid. Also, in dividing groups the nomenclatural type indicates what shall remain in the original group. It is unfortunate that the idea was not conceived under a different name, for morphological types representative of a group have long been recognized and must still be recognized, and physiological or serological types are well established in certain groups. Both these are based on qualities, and are not likely to be identical with nomenclatural types based on priority.

¹ See *Bull. Tor. Bot. Club*, **34**: 167-178, 1907.

² See *Science*, **49**: 333-336, 1918.

A morphological type, chosen for its representativeness, and a nomenclatural type, chosen by priority, are confusing. Furthermore, the use of the word type for anything that is not necessarily typical cannot meet with general favor, no matter how good the principle it covers.

It should here be emphasized that the type concept is an addition or supplement to the principles found in the International Rules and the American Code rather than a substitute for them.

Comparison between the American Code and the Vienna Code.—Both the American Code and the International Rules (known for short as the Vienna Code) have an extensive following among the best systematists of this country. A comparison of the two is therefore in order.

The similarities are much greater than the differences. They agree in their purposes of making botanical nomenclature more uniform, more stable, more appropriate, and more convenient. They use the same categories, beginning with the species. They agree in assigning to each group one exclusive name, and that the oldest usable one, beginning with Linnaeus' "Species Plantarum" (1753) and "Genera Plantarum" (1754). They use the same method of citing the authority for names.

On the other hand the International Rules provide for *nomina conservanda*, names that will be used arbitrarily regardless of the rules, and they require a Latin diagnosis or description of each new name proposed, neither of which is favored by the American Code. By the International Rules a rejected homonym can be again used for a different group while by the American Code it cannot be further used for any group. Lastly, the International Rules make no recognition of the "type concept" of American botanists, unless the non-mandatory recommendation of the Brussels Congress be interpreted as modifying these Rules.

The use of two codes in America has resulted in much confusion and difference in the manuals, which is unfortunate. Probably a uniform following of the International Rules would have served our purposes better up to the present time, but it is still hoped by some that the perpetuation of the American Code will finally result in their improvement through a future compromise.

The Ithaca Congress.—In 1926 an international botanical congress convened in Ithaca, New York, for the consideration of

a wide range of botanical subjects, including nomenclature. It did not enact any legislation in this field but made important progress by the appointment of an interim committee, representing the botanical world, to receive recommendations and report at the next international congress, to be held in London in 1930. It is hoped that at that time a revised code can be agreed upon that will include all that is best in the three just discussed.

Effects of Rules of Nomenclature.—While some botanists have dissented from certain of the International and American rules, their use has been on the whole quite general and has resulted in bringing much order out of the confusion that existed before the adoption of the Paris Code. The few differences in practice that exist now are insignificant compared with those of a century ago.

In one respect the application of the rules has been a source of some annoyance. Botanists have been called upon to abandon many names they had assumed to be correct but which by the rules were unjustifiable synonyms. Some of these were in almost universal use and those who scoffed at efforts toward uniformity resented the reintroduction of earlier terms that had never become prominent, and were considered by them obsolete. To each botanist of this type of mind the list of *nomina conservanda* should include all names he had been using, although out of harmony with the rules. Fortunately the writers of manuals have been generally favorable to unification, although they have differed somewhat in certain details of application, particularly in the code to be followed.

Neglected Legislation.—So far, the work of botanical congresses has been limited principally to one problem: the validity of names. Little has been done to direct the delineation of groups, either species or higher categories. If we agree with Coulter that "Nature makes individuals but men make species," we should also agree with Bessey that species-making and the making of larger groups should have some direction and conform to professional rules. Unfortunately, no such rules have been adopted, and anyone, whether trained or not, can make new groups, or change the categorical rating of existing groups, *e.g.*, give families an order value or vice versa. The most common and most abused form of this privilege is the "splitting" of existing species and other groups. Even a novice can find differences between the individuals that make up a species and can

divide it accordingly into two or more, proposing new names for the new ones. That these differences are too inconstant to be useful, too minute to be detected with certainty by the majority of botanists, or found only in one or two herbarium specimens, no more of which can be found in nature, does not invalidate the names. One of the greatest departures from uniformity in the botanical manuals of this country is in the use or rejection of finely divided species. If a botanical congress could regulate the making of groups it would do much to stabilize nomenclature, but whether or not this is possible is yet undetermined.

CHAPTER VIII

PREPARATION OF HERBARIA

Not until the sixteenth century did botanists make any systematic attempt to preserve for future reference the specimens they studied. Prior to that time a few dried herbs intended primarily as a supply for medicinal purposes served occasionally as comparative material.

About 1550, Cesalpini and his Italian associates and a few Central European botanists began quite definitely to preserve some of the material they studied. The wisdom of this procedure was soon appreciated by others and herbarium-making became a great feature of botanical work. In every civilized country today plant collections of untold value can be found. Probably the greatest is at the Royal Botanic Gardens, Kew, England, while in America the Gray Herbarium at Harvard University and the collections in the National Museum, Washington, D. C., the New York Botanical Garden and the Missouri Botanical Garden are outstanding.

Purposes of Herbaria.—Words are but poor instruments for describing plants. The best description leaves much about the plant unsaid. Many pages would be required to describe a pine tree completely, but species are so numerous that their descriptions must be brief. Furthermore, the different individuals of a species vary somewhat. No two are exactly alike. A specific description, then, is but an approximation. Often the botanist who describes a species is unduly impressed by certain features, especially conspicuous on certain individuals, while he overlooks, minimizes, or ignores other features. As a result other botanists find the specific description unsatisfactory or difficult to apply. Even drawings and photographs fall far short of what is desired in showing individual variation and details of structure and development. In very many cases it is necessary to compare descriptions with actual specimens, many in number and from widely separated regions. This work is of the greatest importance and has resulted in better descriptions and in the dividing

and uniting of groups along more correct lines. To do this revision in the field is usually considered impracticable because time there is too valuable, suitable equipment is not available, and weather conditions are sometimes unfavorable. Furthermore it is less expensive to ship specimens to a few central points where they can be examined than to travel over the world to study them where they grow. As a result of centuries of experience most comparative studies for taxonomic purposes are made in the herbarium and the laboratory. The man who works indoors too exclusively, however, has a narrowness of view that is likely to be evident in his writings. Sometimes, indeed, laboratory and herbarium distinctions must be repudiated because of field observations, as when different herbarium-made species can be found growing on different branches of the same tree.

The working herbarium of today is much used for comparison with new material. Botany is becoming more and more popularized and applied, and in many sections much material of an economic nature is sent to state authorities for examination and report. This material is often fragmentary, lacking reproductive parts, and poorly preserved. It would require a highly experienced systematist to identify it at sight or with books alone, but the average botanist with known specimens for comparison can determine most of it quite handily.

Preserved specimens are also much used to show visitors, both professional and unprofessional, and have become important means of technical and liberal education.

Methods of Collecting.—A satisfactory series in any given species will include specimens in every stage of growth and reproduction, and from different localities and habitats. The most satisfactory single specimen, if only one were available, would be in the flowering stage and from a normal habitat, but a considerable number of plants are required to tell the full story of a species in all its varying aspects.

A complete specimen includes all parts of the plant, even the root. It is impracticable to collect unbroken root systems, however. Furthermore, most specific descriptions do not mention the roots at all. In some cases, however, roots and other underground parts are necessary for identification. A very experienced collector will know which groups require underground portions and which do not, and will be governed accord-

ingly. The beginner should in every case collect enough of the root system of an herbaceous plant to show its general character.

For taxonomic purposes the specimens should be selected to represent the species rather than to suit the fancy of the collector. If few in number they should be the usual rather than the unusual types. If many specimens can be used they should include all types. On account of the limited size of the sheets of mounting paper there is a temptation to select small individuals when large kinds of plants are being collected but this must not be overdone.

Methods of Preservation.—On account of the bulky nature of plants it has long been the custom to press them flat. Admittedly this distorts their shape, but it has been found to be the only practical method for use on a large scale. To produce good herbarium specimens the plants must be pressed before they wilt. The difficulty in doing this is so great that wrinkled specimens are common in many collections. A common method is to collect in a tin vasculum and press immediately on return from the day's trip. With care good results may be had in this way. Generally it is not advisable to wet the plants to delay wilting or to restore turgidity, as this increases the tendency to discolor in the press, although a wet paper lining the vasculum is free from this objection. The finest preservation may be secured by the use of a field press in which the plants may be placed as soon as gathered. For collecting in open country the automobile has become a convenience, but much important work must be done in places inaccessible to it.

A rather standard procedure is followed in pressing plants. They are laid between sheets of newspaper, or plain inner sheets of similar quality, which are alternated between driers of heavy absorbent blotting paper and the whole covered with a board and weight. For use on a field press when traveling, ordinary press boards are too heavy and slatted frames of wood, or of strong cast aluminum are much preferable. In place of a weight the field press is held by straps or clamps. Drying is obtained chiefly by transfer of moisture from the plants into the blotters, and to get good contact and prevent wrinkling the weight should be as heavy as possible without crushing the plant tissue. To prevent discoloration and molding, the driers (but not the inner sheets) must be changed. The number and frequency of changes will depend on the character of the plants and the dryness of the climate. Changing every day for two or three days and then

two or three more times at longer intervals is a good rule, but this is excessive for most plants in an arid region. Considerable judgment and a methodical system are required to secure good specimens with a minimum amount of labor. If the plants are fairly uniform in moisture content all can be kept together and the driers changed at the same time. If some, like grasses, are relatively small and dry while others are thick and succulent they can best be segregated, either when putting into press or when the driers are changed the first time. The succulent ones will require changing long after the others are safely dry.

Under some circumstances it is desirable to use artificial heat to facilitate drying. This method is especially useful in very damp climates, when making heavy collections while moving rapidly from place to place, and when pressing specimens wet with rain or dew. The method is as follows. The specimens are pressed in the usual way for a few hours until wilted. Sheets of corrugated cardboard, smooth on both faces, or of aluminum with fine cross corrugations, are then put between the driers. Some prefer to omit the driers if cardboard is used. The press is then strapped together again with only moderate tightness, and set edgewise over a source of heat with a skirt of canvas to direct the rising hot air through the vertical corrugations. The best source of heat is an electric toaster or hot plate but an oil heater gives good satisfaction. An open wood fire is but a poor makeshift, as it is too hard to regulate and is very likely to scorch the driers. By this method plants can be dried in a fraction of the usual time and with fewer driers, and discoloration of the specimens will be less frequent.

When dry the plants are mounted on sheets of heavy white paper to support them in handling. The standard sheet in this country is $11\frac{1}{2}$ by $16\frac{1}{2}$ inches. The plants are fastened to the sheets by glue or gummed cloth strips or both. Only one plant should be mounted on a sheet no matter how small it is or how many, presumably of the same species, are to be mounted. The label is preferably attached to the lower right-hand corner.

The mounted plants are usually kept in specially constructed herbarium cases. Steel is necessary for safety, as many herbaria have been destroyed by fire to the despair of their owners. The arrangement of specimens in the cases is a matter of convenience. Usually the families are arranged according to a well-known taxonomic system, *e.g.*, that of Engler and Prantl.

Within the families, however, the genera are often arranged alphabetically and within the genera an alphabetical arrangement of species is the rule.

In damp climates especially, it is necessary to avoid basement storage on account of mold. More often, however, particularly in the south, the specimens are damaged by insects that attack the pollen and other parts. Three methods are commonly employed to prevent insect depredations: (1) Sometimes pressed specimens are treated before mounting with an alcoholic solution of corrosive sublimate, applied by dipping or spraying. The alcohol evaporates quickly, without special drying. (2) Most insects are kept away by naphthalene powder sprinkled lightly on each specimen, or by keeping sticks or balls of naphthalene in the cases. This cannot, however, be depended upon to kill insects that have already invaded the collections. (3) In some localities it is necessary to fumigate the specimens with carbon bisulfide. This comes in the form of a liquid that readily changes to a gas when exposed. If the herbarium case is tight the liquid can be placed in a top compartment of it, and the gas, being heavy, diffuses downward among the specimens. Usually, however, it is better to place a few folders of specimens in a tightly covered tin box, add enough carbon bisulfide to saturate the air space, and leave over night or longer if necessary. The gas has a disagreeable odor and is explosive in the presence of an open flame. On account of these objectionable qualities it is hoped that it may be replaced by paradichlorbenzene.

Labeling and Field Data.—The minimum of information to place on each sheet is the botanical name of the specimen, the locality and date of collection, and the name of the collector. It is most unfortunate that so many herbarium specimens bear no other data. Ecologists are now doing splendid work in showing the effects of habitat on morphology, and their work would be made much easier if all preserved specimens available to them bore data concerning soil, moisture, altitude, exposure, etc. There is not the slightest doubt that many individuals of the same species are masquerading under different names because of modifications produced by environment.

The method of recording data used by the best collectors is by the use of a field notebook in which appear numbers to correspond with the specimens collected. The notebook contains much information, the pertinent part of which is later trans-

ferred to the herbarium label. When such data are given they should apply specifically to the individual plant in question, not simply to the usual habitat of that species.

The herbarium should be looked upon as a working tool, and its quality and condition will be reflected in the results obtained from its use.

CHAPTER IX

THE TERMINOLOGY OF SYSTEMATIC BOTANY

Classification and nomenclature are based on a detailed knowledge of comparative plant morphology. Every part of the plant is studied in its minutest detail and compared with similar structures in other plants. For this reason every organ must have a name, and many adjectives must be used to designate the different forms of the organ. It is natural, therefore, that a formidable array of terms should have come into use—the terminology of systematic botany.

The student can make little progress in classifying plants until he has learned the fundamentals of morphology as they are taught in courses in general botany. To this information he must add a special knowledge of the terms used in describing the floral and vegetative organs. The more important of these are discussed in this chapter and should be mastered. For additional ones, used less frequently, the reader is referred to the glossaries found in most descriptive manuals.¹ The terms are here classified in logical sequence under the following headings: roots page 81, stems page 82, buds page 83, leaves page 84, inflorescences page 87, flowers page 89, fruits page 95, and seeds page 96.

ROOTS

Roots differ from stems in the absence of nodes and leaves. They branch at irregular intervals and may produce adventitious buds.

Position :

Primary.—Formed by an extension of the radicle of the embryo.

¹ Much of present-day usage in botanical terminology is derived from two sources which give the terms in classified arrangement with many illustrations: (1) "An Introduction to Botany" by John Lindley, 4th ed., II, 344-383, 1848. Longmans, Green & Co.; (2) "Lessons in Botany," by Asa Gray, rev. ed. 1-128, 1887. American Book Co.

Secondary.—Branching from other roots.

Terrestrial.—Growing in the earth.

Aerial.—Growing in the air.

Adventitious.—Growing from stems or leaves.

Prop.—Growing from the stem above ground and entering the soil for mechanical support.

Morphology :

Tap.—A main root growing straight downward.

Fascicled.—Arranged in a cluster and approximately equal in size.

Fibrous.—Slender, and usually tough.

Fleshy.—Relatively thick in diameter from the presence of stored food.

STEMS

Stems produce nodes at more or less regular intervals, with internodes between. Each node normally bears one or more leaves with a bud in the axil. When these buds form branches, the branches are classed as parts of the stem. Stems may be so specialized that they are not readily recognizable.

Location :

Primary.—Growing from the seed.

Shoot.—Any portion that has been formed by one growing point. Usually it is relatively straight. The shoot does not include its branches, any one of which may also be called a shoot. The term is also used to designate stem and leaves collectively.

Twig.—A short lateral branch of a woody stem, generally bearing foliage leaves and sometimes flowers.

Decumbent.—Lying prostrate, with the tip ascending.

Shape :

Cylindrical.—Circular in cross-section.

Terete.—Same as cylindrical.

Quadrangular.—Square in cross-section.

Texture :

Herbaceous.—Dying to the ground at the end of the season's growth.

Woody.—Living over winter and hard in texture.

Shrubby.—Woody, with more than one trunk.

Suffrutescent.—Woody at the base, the upper portion dying back at the end of the season.

Specialized Stems :

Rootstock.—A horizontal underground stem bearing scale-like leaves and usually shoots and adventitious roots. Its functions are food storage and vegetative propagation.

Rhizome.—Same as rootstock.

Tuber.—A fleshy underground stem bearing scale-like leaves with buds in their axils. Its function is food storage and vegetative propagation. It differs from a rootstock in being proportionately shorter and thicker.

Corm.—The fleshy underground base of a stem, usually spherical in shape or broader than high. Its functions are food storage and vegetative propagation.

Bulb.—A rounded underground structure consisting of a short basal stem bearing fleshy scale-like leaves which make up the bulk of the organ. Its functions are food storage and vegetative propagation.

Tendrils.—A lateral climbing organ, sometimes stem and sometimes leaf.

Thorn.—A strong, sharp-pointed, protective organ. It may be a lateral branch, extrusion of the cortex, or part of a leaf.

Prickle.—Like a thorn but weaker.

Cladophyll.—A stem having the appearance and functions of a leaf.

BUDS

Buds are very short stems, usually lateral branches, bearing specialized leaves.

Kinds:

Dormant.—Inactive, usually because of the winter or dry season.

Leaf.—Those that are the beginnings of shoots and do not contain floral parts.

Flower.—Unopened flowers.

Mixed.—Dormant buds that contain undeveloped foliage leaves with flower buds wrapped up inside them.

Position:

Terminal.—At the ends of shoots and terminating the season's growth.

Lateral.—In the axils of leaves or leaf scars.

Adventitious.—Growing from roots or leaves.

Coverings:

Scaly.—Covered with scale-like leaves.

Naked.—Without scale-like leaves covering the parts that are to become foliage leaves or floral parts.

LEAVES

Leaves are temporary organs having primarily the functions of transpiration, respiration, and photosynthesis, but often specialized for other purposes. They are always borne on the nodes of stems.

Duration :

Deciduous.—Falling off soon after maturity.

Evergreen.—Remaining in place and functioning for one or more years after formation.

Persistent.—Not deciduous. Evergreen.

Fugacious.—Falling almost as soon as formed. Applied most often to stipules.

Arrangement on the Stem :

Alternate.—One leaf at a node and so arranged that a line drawn on the stem through the leaf bases will take a spiral course up the stem.

Opposite.—Two leaves at a node on opposite sides.

Whorled.—More than two leaves at a node in a circle around it.

Verticillate.—Same as whorled.

Bract.—A relatively small leaf just below an inflorescence, flower, or floral part.

Subtend.—To enclose in its axil. Used in reference to a bract or a leaf, to indicate its position below a bud, inflorescence, flower, or floral part.

Leaf Parts :

Blade.—The flat expanded portion.

Petiole.—The leaf stalk (not to be called a stem).

Stipules.—Two scale-like attachments at the base of the petiole. They may be specialized into spines.

Dorsal Surface.—The application of this term to distinguish between the upper and lower surfaces of leaves is in a chaotic condition. Dorsal is from *dorsum* meaning back. In the animal kingdom the back is generally the upper surface. In the plant kingdom, however, it is conceived that the surface of the leaf away from the stem axis is the back, and as the leaf assumes a horizontal position this becomes the under surface. That the same term should be applied to the upper surface of an animal and of the thallus of a liverwort, and to the lower surface of a

leaf seems inconsistent; especially as it is but an analogy to call the surface of a leaf away from the axis the back. Hence there is a disposition among botanists to call the upper surface the dorsal and the lower surface the ventral, but usage is not uniform.

Ventral Surface.—The opposite of dorsal.

Absence of Parts:

Sessile.—Without petiole, the blade attaching directly to the stem.

Exstipulate.—Without stipules.

General Shape:

Linear.—Very narrow, with parallel margins.

Lanceolate.—Narrow, and tapering toward the ends like the head of a lance.

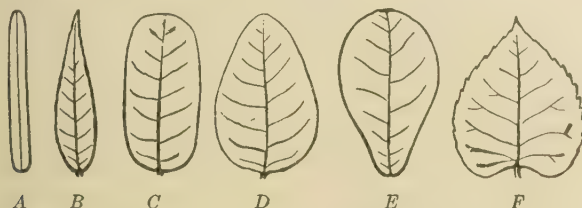


FIG. 3.—Shapes of leaves. *A*, linear. *B*, lanceolate. *C*, oblong. *D*, ovate. *E*, obovate. *F*, cordate. (After Gray.)

Oblong.—About twice as long as broad, with the sides nearly parallel through the middle portion.

Ovate.—Like the longitudinal section of a hen's egg, or narrower, with the petiole attached to the broad end.

Obovate.—Like ovate, but with the petiole at the narrow end.

Cordate.—Heart shaped. Broadly ovate, with base extending in two blunt lobes.

Peltate.—With the petiole attached to the lower surface of the blade inside the margin.

Perfoliate.—The sessile blade clasping the stem, which appears to run through it.

Compounding:

Simple.—With the blade in one piece.

Compound.—With the blade divided into several distinct parts. Usually each of these parts (leaflets) is attached to the midrib or stalk by a definite articulation.

Leaflet.—One of the parts of a compound leaf blade.

Pinnate.—With the leaflets attached at different points along the petiole.

Palmate.—With the leaflets attached practically at the same point, at the end of the petiole.

Decompound.—With the leaflets compounded.

Margins :

Entire.—Without indentations of any sort.

Dentate.—With teeth pointing outward.

Serrate.—With teeth pointing toward the apex.



FIG. 4.—Margins of leaves. A, serrate. B, dentate. C, crenate. D, lobed. E, cleft. F, lacinate. G, divided. (After Bastin.)

Lobed.—With relatively few, large, shallow indentations.

Cleft.—With a few incisions extending halfway to the center or a little deeper.

Crenate.—With rounded or blunt teeth. Scalloped.

Divided.—With incisions extending to the midrib or main veins. Almost compound.

Lacinate.—With many deep, narrow incisions.

Base :

Tapering.—The blade extending downward along the petiole.

Sagittate.—The base of the blade extended into two lobes that point downward or slightly inward.

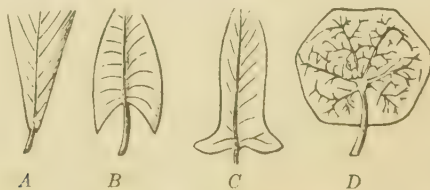


FIG. 5.—Bases of leaves. A, cuneate. B, sagittate. C, hastate. D, peltate. (After Bastin.)

Hastate.—Like sagittate, but with the basal lobes diverging from the petiole.

Apex :

Accuminate.—With a long, slender, sharp point.

Acute.—With a point forming an acute angle.

Obtuse.—Blunt pointed.

Emarginate.—With a shallow notch at the tip.

Mucronate.—With a broad apex ending abruptly in a sharp tip.

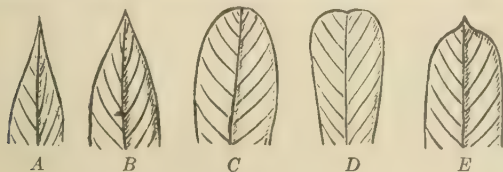


FIG. 6.—Apices of leaves. A, acuminate. B, acute. C, obtuse. D, emarginate. E, mucronate. (After Bastin.)

Venation:

Veins.—Vascular bundles of leaves.

Midrib.—A large main vein running lengthwise through the blade from petiole to tip.

Parallel.—Running side by side without branching or intersecting.

Netted.—Running in all directions, branching and intersecting.

Reticulate.—Same as netted.

Palmate.—The main veins radiating from the point where the petiole joins the blade.

Pinnate.—Having a midrib with smaller veins branching from it.

Surface Coverings:

Glabrous.—Without hairs of any kind.

Glaucous.—Covered with a whitish waxy coating (bloom), that easily rubs off.

Pubescent.—With fine, soft, short hairs.

Villous.—With long, silky, straight hairs.

Hirsute.—With moderately stiff hairs.

Hispid.—With stiff, bristly hairs.

Tomentose.—With long, curled, matted hairs (woolly).

INFLORESCENCES

When flowers are borne close together, thus forming a natural cluster, this is called an inflorescence. An inflorescence is, in reality, a closely branching stem, each branch bearing a flower. If the branches are far apart, the term inflorescence is not applied, and naturally this is an intergrading character. Some inflorescences are clear-cut, typical, and easily distinguished. Others may grade into each other or be so irregular that they are hard to recognize by description.

Compounding :

Simple Inflorescence.—One in which only the main flower stem branches.

Compound Inflorescence.—One in which the flower stems branch two or more times.

Parts :

Rachis.—The main flower stem to which the other parts are attached.

Pedicel.—The individual stalk of each flower in an inflorescence.

Types :

Indeterminate.—With flowers opening in succession rather than simultaneously. The lower or outside ones open first and in extreme cases new buds continue to appear at the tip throughout the season.

Determinate.—With all the flowers opening at about the same time, or the central ones a little in advance, and a terminal flower preventing a continued production of flower buds by the stem.

Raceme.—An indeterminate inflorescence consisting of a central rachis bearing pedicelled flowers along its sides, the different pedicels about equal in length when mature.

Spike.—An indeterminate inflorescence consisting of a central rachis bearing sessile flowers along its sides. Spikes and racemes are intergrading.

Ament.—A spike bearing apetalous unisexual flowers. It is usually pendulous and deciduous.

Catkin.—Same as ament.

Corymb.—An indeterminate inflorescence consisting of a central rachis with pedicelled flowers along its sides, the lower pedicels much longer than the upper, giving the inflorescence a flat or rounded top. The outside flowers borne by the lower pedicels open a little earlier than the central upper ones. Corymbs and racemes are intergrading. Simple corymbs are rather rare.

Head.—A compact indeterminate inflorescence, with sessile flowers attached as nearly as possible at one point, *i.e.*, on the expanded top of the stem. Heads intergrade with spikes, racemes, and umbels.

Umbel.—An indeterminate inflorescence with several pedicelled flowers attached practically at the same point on the top of the stem. The outside flowers open in advance of the inner ones.

In general effect the umbel and corymb are similar in appearance, the difference being in the attachment of the pedicels.

Panicle.—An indefinitely branching inflorescence. It is practically a long-pedicelled, loosely branching, compound raceme or corymb.

Cyme.—A few-flowered, flat-topped, determinate inflorescence in which the central terminal flowers open slightly in advance of the outer ones. Most cymes occur on plants with opposite leaves or in axillary clusters.

Spadix.—An inflorescence consisting of a fleshy central column, bearing many stamens below and many pistils above. The spadix is surrounded by a large bract or spathe, usually showy, giving the whole the effect of a single flower.

FLOWERS

Flowers are the special reproductive systems of the Spermatophyta. Some would restrict the term flower to the angiosperms, thus excluding the strobilus of the gymnosperms. A functional flower must contain at least one microsporophyll (stamen) or macrosporophyll (carpel). Most flowers contain several of each and certain accessory organs, *i.e.*, petals and sepals.

The normal arrangement of floral organs is in four whorls or circles in the following order from the outside inward: (1) sepals (calyx), (2) petals (corolla), (3) stamens (androecium), and (4) pistils (gynoecium).

Floral Organs.—Certain parts of the flower are specialized stems, namely:

Peduncle (or in the case of an inflorescence the *pedicel*). The flower stalk.

Receptacle.—The expansion at the top of the peduncle which bears the carpels, and often all the other floral organs.

Torus.—Same as receptacle.

Hypanthium.—The cup-shaped receptacle of a cotyled flower.

The other floral organs are specialized leaves. They are:

Calyx.—The collection of sepals that encloses the rest of the organs in the bud.

Corolla.—The circle of petals just inside the calyx and usually forming the showy part of the flower.

Stamen.—A microsporophyll found just inside the corolla and producing the pollen grains.

Filament.—The microsporangiphore or stalk of the stamen.

Anther.—The microsporangium which contains the pollen grains (microspores).

Staminode.—An abortive stamen, usually the filament only, which may even be reduced to a scale or tiny projection.

Pistil.—The central organ of the flower, composed of one or more carpels.

Carpel.—A macrosporophyll enclosing one or more ovules (macrosporangia).

Ovule.—The body that develops into a seed.

Ovary.—The expanded basal portion of the pistil, containing the ovules.

Stigma.—The tip of the pistil which is receptive to the pollen grains and on which they germinate.

Style.—The slender portion that connects the ovary with the stigma, and holds the latter in position to receive the pollen grains.

Bract.—A leaf or scale in whose axil an inflorescence, flower, or floral organ is produced.

Spathe.—A large, usually showy, bract at the base of a spadix or other inflorescence and enclosing it.

Involucre.—A series of scale-like leaves at the base of a flower or an inflorescence.

Types of Flowers :

Complete.—Containing all of the different kinds of floral organs.

Bisexual.—With both stamens and pistils.

Perfect.—Same as bisexual.

Hermaphrodite.—Same as bisexual.

Unisexual.—With stamens or pistils but not both.

Imperfect.—Same as unisexual.

Staminate.—With stamens but not pistils. Also called male.

Pistillate.—With pistils but not stamens. Also called female.

Monocious.—The same individual plant producing both staminate and pistillate flowers.

Diocious.—The same individual plant bearing staminate or pistillate flowers but not both.

Polygamous.—The same or different individual plants producing both bisexual and unisexual flowers.

Anemophilous.—Adapted for wind pollination.

Entomophilous.—Adapted for insect pollination.

Floral Axis :

Strobiloid.—With a convex or flat receptacle to which the other floral organs are united.

Cotyloid.—With a receptacle that is concave, sometimes to the extent of surrounding the carpels.

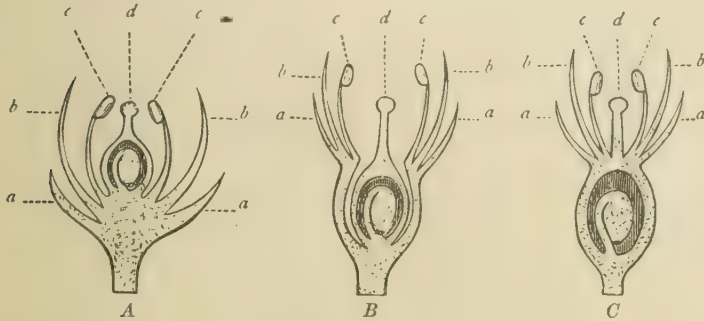


FIG. 7.—Floral axis. *A*, strobiloid flower, showing hypogynous insertion of sepals, petals, and stamens. *B*, cotyloid flower showing perigynous insertion, the receptacle extending to form an hypanthium. *C*, epigynous insertion in cotyloid flower. (After Bastin.)

Insertion :

Hypogynous.—Calyx, petals, and stamens attached to the receptacle at the base of the ovary, which is superior. Applies to strobiloid flowers.

Perigynous.—Petals and stamens attached to the margin of a cup-shaped extension of the receptacle (hypanthium) or united to the calyx tube, and apparently growing from it. At least the upper half and usually all of the ovary is free from the surrounding parts. Applies to cotyloid flowers.

Epigynous.—Sepals, petals, and stamens apparently growing from the top of the ovary, but in reality from the hypanthium which extends up around the ovary and adheres to it. Applies to cotyloid flowers.

Arrangement of Floral Parts :

Aestivation.—The arrangement of floral parts in the bud. Some restrict the term to the perianth.

Imbricated.—With the sepals or petals overlapping each other at the margins.

Valvate.—With the sepals or petals abutting at their margins but not overlapping.

Number of Floral Parts :

-merous.—An ending, which, taken with a numerical prefix indicates the number of each of the floral parts. For example, in a 5-merous (pentamerous) flower, sepals, petals, stamens, and carpels are in fives or multiples of five.

Union of Parts :

Symphysis.—The union of like parts with each other in the process of formation, as the symphysis of petals.

Coalescence.—Same as symphysis.

Cohesion.—Same as symphysis.

Connate.—United with like members in the process of formation, as filaments connate with each other.

Adnate.—United with a different kind of organ in the process of development, as, the calyx tube adnate to the ovary.

Adherent.—Same as adnate.

Free.—Not adnate, as the ovary free from the receptacle.

Distinct.—Not connate or coalescent, as the sepals distinct from each other.

Connivent.—Coming together without uniting, or but slightly adherent.

Calyx :

Distinct.—Sepals not united to each other.

Tubular.—Sepals united to each other except at the toothed margins.

Nerve.—Vein in a sepal, petal, carpel, bract, or scale.

Pappus.—Bristles or scales on an achene, representing the persistent calyx.

Perianth.—Calyx and corolla collectively.

Scabrous.—Rough and harsh to the touch.

Scarious.—Thin and dry, with little or no chlorophyll.

Corolla :

Apetalous.—Without petals, or the petals reduced to inconspicuous scales.

Polypetalous.—Each petal distinct from the others.

Gamopetalous.—With petals united to each other at their margins to form a tube or funnel.

Monopetalous.—Same as gamopetalous.

Sympetalous.—Same as gamopetalous.

Regular.—With all petals of the same shape.

Actinomorphic.—Same as regular.

Symmetrical, or Radially Symmetrical.—Same as regular.

Irregular.—Bilaterally symmetrical, with petals of different shapes.

Zygomorphic.—Same as irregular.

Stamens :

Androecium.—The collection of stamens in a flower.

Monadelphous.—With filaments united into a tube or column.

Diadelphous.—With filaments united into two sets.

Versatile.—The anther attached near the middle to the tip of the filament.

Introrse.—The anther facing the center of the flower.

Extrorse.—The anther facing the periphery of the flower.

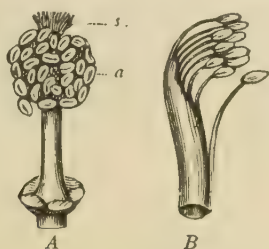


FIG. 8.—Coalescence of stamens. *A*, monadelphous. *B*, diadelphous. (After Bastin.)

Staminode.—A sterile stamen, *i.e.*, one that has no functional anther, and may be reduced to only a tiny projection representing the base of a filament.

Pistils :

Gynoecium.—The collection of carpels in a flower, whether separate or united into one pistil.

Inferior Ovary.—Embedded in the receptacle, resulting in an epigynous insertion of petals and stamens.

Superior Ovary.—Set on top of the receptacle, with the insertion of petals and stamens hypogynous or perigynous.

Simple.—A unicarpellate pistil.

Compound.—A pistil of two or more united carpels. It may contain one or more chambers.

Cell.—One of the chambers or cavities in a pistil, containing the ovules. A rather unfortunate term owing to its different meanings.

Placenta.—The part of the ovary to which the ovules are attached. This is usually the margin of the carpel.

Axile Placentation.—Each carpel entirely closed, thus making as many chambers as carpels, with the placentae at the center of the pistil (if compound).

Parietal Placentation.—Each carpel more or less open, with margins of adjacent ones coherent, thus forming a one-chambered compound ovary with placentae on the walls at the lines of union.

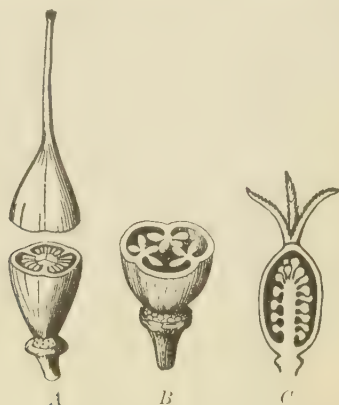


FIG. 9.—Placentation. A, axile. B, parietal. C, free central. (After Gray.)

Central Placentation.—In an ovary of more than one carpel, the ovules attached to a compound placenta that rises as a column from the base. This column may be formed by the suppression of the portion of the carpels that forms the partition or by an extension of the carpels where they join at the base.



FIG. 10.—Types of ovules. A, orthotropous. B, campylotropous. C, amphitropous. D, anatropous. (After Bastin.)

Ovules :

Orthotropous.—The ovule symmetrical and straight with the chalaza at the base and the micropyle at the tip.

Anatropous.—The ovule symmetrical but completely inverted so that the apparent tip is really the chalaza and the micropyle is close to the stalk, which is adnate the entire length of the ovule.

Amphitropous.—The ovule symmetrical but half inverted, so that the stalk appears to attach at the side.

Campylotropous.—The ovule asymmetrical and curved so as to bring the base and micropyle close together.

FRUITS

Strictly speaking, the true fruit is a ripened ovary. It may, however, have various appendages—receptacle, involucre, calyx, style, etc.,—which are commonly included under the term fruit.

Parts of Wall.—Many fruits have three layers in the wall, but these may be intimately blended.

Pericarp.—The wall of the fruit considered as a whole.

Exocarp.—The outer layer of the pericarp, including the skin.

Mesocarp.—The middle layer of the pericarp.

Endocarp.—The inner layer of the pericarp, including the lining wall of the seed chamber.

Character of Wall:

Fleshy.—Relatively soft and juicy.

Dry.—Relatively hard and tough.

Dehiscent.—Opening naturally, in the case of a dry fruit, to permit the escape of the seeds.

Suture.—The line along which the parts separate in dehiscence.

Valve.—One of the segments into which the walls of a fruit separate by dehiscence.

Kinds of Fruits.

Simple.—Composed of a single ripened ovary.

Aggregate.—Composed of several ripened ovaries from a single flower, joined together by a common receptacle.

Multiple.—The ripened ovaries of several flowers borne in a compact spike and joined together in maturity.

Pod.—A unicarpellate fruit, generally dehiscing along both dorsal and ventral sutures.

Legume.—Same as pod (also the common name of any member of the Leguminosae).

Follicle.—A unicarpellate fruit, dehiscing along the ventral suture only.

Loment.—A segmented pod.

Capsule.—A many-seeded, dry, usually dehiscent fruit. (Generally applied to those of two or more carpels.

Silique.—A special, long, slender capsule of two carpels, found in the mustard family.

Silicle.—A special, short, broad capsule of two carpels, found in the mustard family.

Achene.—A small, dry, indehiscent, one-seeded fruit, the seed readily separating from the ovary wall. It may be either plumed or naked.

Caryopsis.—A seed-like fruit resembling an achene, but having the seed coat firmly united to the ovary wall. Especially common in the Gramineæ.

Samara.—Like an achene, but winged.

Utricle.—An achene with a loose involucre covering.

Nut.—Like an achene but larger, and usually resulting from a compound ovary. It is generally enclosed in a husk composed of a developed involucre.

Pome.—A several-carpellate, several-seeded, fleshy fruit, in which the wall is a combination of carpels and receptacle. It results from the development of an inferior ovary with its appendages.

Drupe.—A one-seeded, fleshy fruit, developed from a superior ovary, the endocarp taking the form of a hard "stone." The term is sometimes restricted to unilocular fruits.

Berry.—A several-carpellate, several-seeded, fleshy fruit with pericarp entirely soft. It may be formed from either an inferior or a superior ovary. It differs from a pome in having the carpels soft in texture.

SEEDS

The seed is a ripened ovule. It consists of the wall of the macrosporangium, the nucellus (which may be more or less absorbed), one or more seed coats, and an embryonic plant. Many seeds contain also an endosperm, developed from the female gametophyte and richly stored with food.

Parts of the Seed:

Integument.—One of the layers (of which there are usually two) that grow around the macrosporangium from its base and form the walls of the ovule and hence the seed coats.

Testa.—The outer integument.

Endosperm.—The region of food storage outside the embryo. It originates from a union of the second sperm nucleus with the embryo-sac nucleus.

Embryo.—The young plant developed from the fertilized egg cell.

Funiculus.—The seed stalk.

Hilum.—The scar on a seed left by its separation from the funiculus.

Chalaza.—The place where the seed coats unite with the rest of the ovule.

Micropyle.—An opening where the integuments have not completely grown over the ovule. The pollen tube grows through this opening to fertilize the egg cell.

CHAPTER X

THE LITERATURE OF SYSTEMATIC BOTANY

Publications dealing directly or indirectly with the systematic aspect of botanical science have always held a conspicuous place in botanical literature; indeed, a mere list of titles would consume hundreds of pages. The student will be given here but a few representative examples of different phases of the subject.

MEDIA FOR TAXONOMIC PUBLICATION

The earliest botanical works were written before the invention of the printing press and took the form of manuscripts, often bound in book form. Some of the most important of these have since been copied either as *facsimile* impressions or by printing, either with or without translation.

In recent years taxonomic publication has taken varied forms—research articles, monographs, general treatises, manuals, etc. A few botanical journals are given over quite largely to publications of this kind but the general tendency is to include articles on taxonomy and nomenclature with those on morphology, physiology, and more general topics. It is, therefore, quite impossible to designate any publication or group of publications where articles of this character are chiefly found.

From the standpoint of establishing priority in the publication of names and descriptions of groups, all botanical works—journals, books, bulletins, etc., in regular circulation are given equal recognition, and, indeed, priority can be established through works not strictly botanical, although their use is unfortunate, as articles they contain may easily be overlooked by those most interested in them.

THE CLASSICS

In the older literature a few works stand out as remarkable productions for the period in which they were written. Most of these have profoundly influenced the development of the science.

"Historia Plantarum."—Written by Theophrastus in ten volumes about three centuries B.C. Stapelius edition, Amsterdam, 1644.

"Enquiry into Plants."—Written by Theophrastus in eight volumes, the last two lost. Translated into English by Sir Arthur Hort in 1916; Wm. Heinemann, London.

These two works by Theophrastus are considered the oldest writings of value on botanical subjects existing today. They contain much real botanical information mixed with speculative philosophy, and express freely the beliefs of the times, although in many cases the author casts doubt upon the superstitious ideas that he records.

"De Re Rustica."—Written by Marcus Porcius Cato more than a century B.C. and published in 1494. The book is devoted largely to agricultural and horticultural practices, methods of propagation, culture, varieties, etc., but plants are quite generally designated binomially, and many of these names are still in use. Said to be the oldest botanical work written in Latin.

"Genera Plantarum."—Written by Carolus Linnaeus, Upsala University. Fifth edition, 1764, 500 pages unillustrated. This edition is official in establishing the limit of priority for generic names. It describes 1,105 genera of plants of all kinds, citing the authority for the name in most cases. In general the generic descriptions of the seed-bearing plants are restricted to the flower, fruit, and seed, ignoring vegetative portions.

"Species Plantarum."—Written by Carolus Linnaeus, Upsala University. First edition, 1753, two volumes, 1,200 pages, unillustrated; *Facsimile* edition, W. Junk, Berlin. In this, the most used of the botanical classics, Linnaeus assembled under their genera practically all the species described up to that time, using very largely the binomial system, but indicating varieties in some cases. Generic descriptions were not included. The work was partly the result of his own observations, and partly compilation. A few previously published descriptions were overlooked, but the "*Species Plantarum*," was such a landmark in nomenclatural development that it was adopted as a starting point for priority in botanical names.

"Genera Plantarum."—Written by G. Bentham and J. D. Hooker, Kew, England. First edition, 1862 to 1883, three volumes, 3,577 pages, unillustrated; published by Reeve & Co., London. This monumental work gives a fairly complete classifi-

cation of the higher plants with a definite system of categories and descriptions of all groups. The sequence is dicotyledons, gymnosperms, and monocotyledons. This work has dominated the field of systematic botany more than any other unless it be the "Naturliche Pflanzenfamilien," of Engler and Prantl.

FUNDAMENTAL PRINCIPLES

The orderly taxonomic work of today is based on many principles that are the results of much painstaking research. Some of these have been known so long that their origin is obscure, others represent bold advances taken in recent times.

"Lessons in Botany."—By Asa Gray, Harvard University. Revised edition, 1887, 226 pages and 589 text figures; American Book Company. While this book covers, in a way, the field of general botany, its great value lies in the clear-cut descriptions of reproductive and vegetative structures,—flowers, fruits, leaves, etc.—and its excellent definitions and distinctions. It furnishes the groundwork for most glossaries of systematic works.

"Flowering Plants and Ferns."—By J. C. Willis, Royal Botanic Garden, Ceylon. Third edition, 1908, 712 pages, illustrated; Cambridge University Press. The first quarter of the book is devoted to a discussion of principles of taxonomy, special morphology, systems of classification, and suggestions to collectors. The treatment is excellent for the date at which it was written.

"The Phylogenetic Taxonomy of Flowering Plants."—By Charles E. Bessey, University of Nebraska; *Ann. Mo. Bot. Gard.*, Vol. 2, 1915, 155 pages, illustrated by one figure showing graphically the author's ideas of the relationships of the angiosperms. He sets forth many principles of taxonomy, and, based on these principles, constructs a phylogenetic system of classification of the angiosperms.

"Descriptive Systematic Botany."—By A. S. Hitchcock, U. S. Department of Agriculture. First edition, 1925, 216 pages, unillustrated; John Wiley & Sons, Inc. An excellent reference book on many topics relating to collecting, identifying, and the scientific arrangement of plants. The different codes of nomenclature are presented in comparison.

"The Generic Concept in the Classification of Flowering Plants."—By B. L. Robinson, Harvard University; *Science*, Vol. 23, pages 81-92, 1906. The author here sets forth ideas

regarding the correct delineation of genera and seeks to discourage the making of new genera on insufficient grounds.

"Aspects of the Species Question."—By C. E. Bessey, N. L. Britton, J. C. Arthur, D. T. MacDougal, F. E. Clements, and H. C. Cowles; *Am. Nat.*, Vol. 42, pages 218–281, 1908. A symposium giving a masterful presentation of the best American ideas on the species concept, and especially on the problem of finely divided species or subspecies.

"Evolution by Means of Hybridization."—By J. P. Lottsy. First edition, 1916, 166 pages and 2 illustrations; Martinus Mijhoff, The Hague. A discussion well adapted to student use. The author dwells especially on the part played by conjugation in the formation of new species and varieties.

"What Evolution Is."—By George H. Parker, Harvard University. First edition, 1926, 173 pages and 4 pages of illustrations; Harvard University Press. A highly authoritative, dispassionate presentation of the history, evidences, and mechanism of evolution as it has been disclosed by more than half a century of investigation by many careful workers. The book is suited to students and general readers.

"Evolution for John Doe."—By Ward Henshaw. First edition, 1925, 354 pages, illustrated; The Bobbs-Merrill Company. The author, a layman, has studied the subject from all angles, and here presents a good, readable account of it that will appeal to other laymen.

"International Rules of Botanical Nomenclature."—By John Briquet, Reporter General for the International Botanical Congress of Vienna 1905 and Brussels 1910. Second Edition, 1912, unillustrated; Gustav Fischer, Jena. Written in three languages, French, English, and German, in one volume with index. The English section covers 19 pages and the entire work 110 pages, of which 29 are devoted to *nomina conservanda* in Latin, applicable to the three sections.

"American Code of Botanical Nomenclature."—By the American Nomenclature Commission; *Bull. Torr. Bot. Club.*, Vol. 34, pages 167–178, 1907, unillustrated. A brief statement of the reasons for advocating the American Code as a substitute for the recently formulated International Rules, followed by the rules themselves.

"Type-basis Code of Botanical Nomenclature." By A. S. Hitchcock, U. S. Department of Agriculture, 3 pages, unillus-

trated; *Science*, Vol. 49, 1919, pages 333-336, unillustrated. The author, as chairman of a committee of the Botanical Society of America on generic types, here makes a brief report of the committee, and records the rules recommended for adoption and known as the "Type-basis Code."

DESCRIPTIVE MANUALS

The works most used by students of systematic botany are those with analytical keys, and descriptions of families, genera,

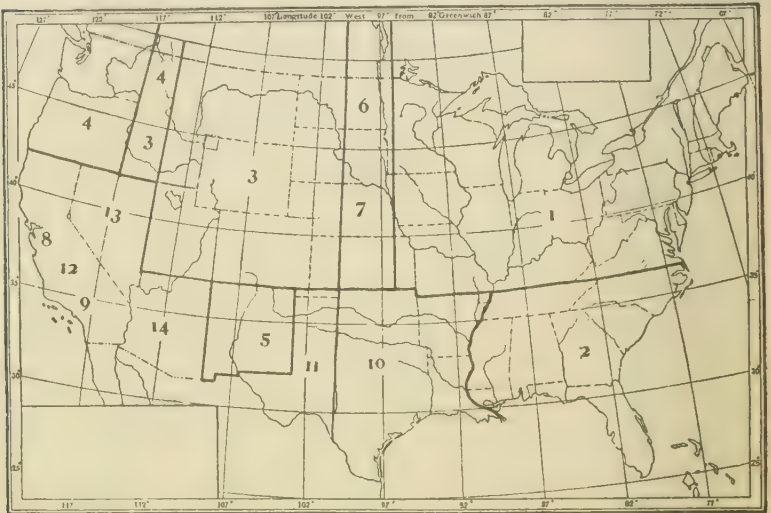


FIG. 11.—Range covered by the principle botanical manuals of the United States. (Redrawn after Conrad.)

KEY TO NUMBERS ON MAP

1. Gray's "Manual of Botany." Britton's "Manual." Britton and Brown's "Illustrated Flora" (includes 6 and 7). 2. Chapman's "Flora of the Southern United States." Small's "Flora of the Southeastern United States" (includes 10). 3. Rydberg's "Flora of the Rocky Mountains." Coulter and Nelson's "New Manual of the Rocky Mountains." 4. Howell's "Flora of Northwest America." Piper's "Flora of Washington." Piper and Beattie's "Flora of the Northwest Coast." 5. Wooten and Standley's "Flora of New Mexico." 6. Bergman's "Flora of North Dakota." 7. Petersen's "Flora of Nebraska." 8. Jepson's "Flora of Western Middle California." Jepson's "Flora of California." Jepson's "Manual of the Flowering Plants of California." Abram's "Illustrated Flora of the Pacific States." 9. Abram's "Flora of Los Angeles and Vicinity." 10. See 2. 11. Coulter's "Manual of Western Texas." 12. Smiley's "Flora of the Sierra Nevada of California." 13. Watson's "Botany of the United States Geological Exploring Expedition." 14. See 5 and 13.

and species. In a general way all such works are classed as manuals. Where they cover the flora of the entire world, or any large area, they are necessarily voluminous unless painfully condensed; consequently most of them are restricted to certain regions only. Fortunately nearly all parts of the United States are well covered (see Fig. 11).

"Die Naturlichen Pflanzenfamilien."—By Adolph Engler, Berlin, and K. Prantl, Breslau. First edition 1887 to 1909, second edition in preparation. The largest work of its kind ever written, filling 23 volumes and occupying several feet of shelf space. Profusely illustrated; Wilhelm Engelmann, Leipzig. This great work covers the entire plant kingdom and is worldwide in its scope. It carries the classification to genera and in some cases to species, but there is considerable lack of uniformity in treatment owing to its composite authorship, many botanists having taken part in the preparation of the treatise. This publication has dominated the field of systematic botany since its publication, but there is at present a considerable breaking away from its phylogenetic conceptions (see p. 59).

"Syllabus der Pflanzenfamilien."—By Adolph Engler and Ernst Gilg, University of Berlin. Tenth edition, 1924, 420 pages and 462 illustrations; Gebrüder Bornträger, Berlin. This book is usually thought of as a condensation of "Die Naturlichen Pflanzenfamilien." It consists of an introduction on principles of classification, a list of families and higher categories according to the Engler system, and a brief discussion of families and tribes.

"Systematische Botanik."—By Richard Wettstein, University of Wien. Third edition, 1923-1924, two volumes combined, 1,017 pages and 1,905 illustrations; Franz Deuticke, Leipzig. The great value of this work lies in its modern conceptions and its excellent descriptions and illustrations.

"The Classification of Flowering Plants."—By A. B. Rendle, British Museum, Volume I, Gymnosperms and Monocotyledons. First edition, 1904, 403 pages and 187 illustrations. Volume II, Dicotyledons. First edition, 1925, 636 pages and 279 illustrations; Cambridge University Press. This work makes no pretense of listing all species, but gives remarkably fine descriptions of all the families, the morphological tendencies within the families, and the modifications of the family types. It is particularly strong in indicating the morphological equivalents of highly specialized organs. Examples are drawn from the flora of the entire world.

"The Families of Flowering Plants."—By J. Hutchinson, Royal Botanic Gardens, Kew, England. Vol. I, Dicotyledons. First edition, 1926, 328 pages and 264 illustrations, with an elaborate diagram of phylogenetic arrangement. Vol. II on Monocotyledons to be issued; Macmillan & Co., Ltd., London.

Hutchinson's work represents the latest general exposition of the flowering plants. It is refreshing in its originality, with a number of progressive features: a statement of phylogenetic principles; a new phylogenetic scheme (reviewed on p. 58) which is bound to provoke fruitful discussion; a grouping of the orders and families according to their characters, tendencies, and consequent affinities; an extensive key to families, worldwide in its scope; a concise and well-illustrated description of each family, accompanied in many instances by a distribution map.

"Gray's New Manual of Botany."—Earlier editions by Asa Gray, Harvard University. Seventh edition, 1908, revised by B. L. Robinson and M. L. Fernald, Harvard University, 926 pages and 1,036 illustrations; American Book Co. No work of its kind is better known or more used than Gray's Manual. The analytical keys have been thoroughly tested and the descriptions are concise but clear. The illustrations, though small, are well chosen. In this seventh edition the International Rules of nomenclature are followed.

"Illustrated Flora of the Northern States and Canada."—By Nathaniel Lord Britton and Addison Brown, New York Botanical Garden. Second edition, 1913, three volumes with a total of 1,652 pages and 4,666 figures; Charles Scribner's Sons. This work has proved exceedingly usable due to its excellent organization, clear descriptions, and numerous figures. It has become a desk reference for every American botanist whether working strictly within its range or not. It follows the American Code of nomenclature.

"Manual of the Flora of the Northern States and Canada."—By Nathaniel Lord Britton, New York Botanical Garden. Third edition, 1907, 1,122 pages, unillustrated; Henry Holt and Company. The manual is based on the first edition of Britton and Brown's "Illustrated Flora," putting that work in convenient form for student use. It follows the rules of nomenclature adopted at Rochester, 1892, and Madison, 1893, supplementing the Paris code.

"Flora of the Southeastern United States."—By J. K. Small, New York Botanical Garden. Second edition, 1913, 1,394 pages, unillustrated; published by the author. This work is indispensable for a study of the flora of the southeastern fourth of the United States and is admirably executed. It follows the American Code of nomenclature.

"New Manual of Rocky Mountain Botany."—By John M. Coulter, University of Chicago, and Aven Nelson, University of Wyoming. Second edition, 1909, 646 pages, unillustrated; American Book Company. This book, of convenient classroom size, is drawn on lines similar to "Gray's Manual," but adapted to the flora of a vastly different region. It has proven a highly useful work for a large area of the country. It follows, for the most part, the International Rules of nomenclature.

"Flora of the Rocky Mountains and Adjacent Plains."—By P. A. Rydberg, New York Botanical Garden. First edition 1917, 1,110 pages, unillustrated; published by the author. Rydberg's flora covers a somewhat wider range than Coulter and Nelson's manual and includes many more genera and species. This increase in numbers is due not only to the wider range and later date of publication, giving opportunity for more intensive collection, but also to the author's tendency to divide existing groups, especially genera and species. The American Code of nomenclature is followed.

"Manual of the Flowering Plants of California."—By Willis L. Jepson, University of California. First edition, 1925, 1,238 pages and 1,023 illustrations; published by the Associated Students Store, University of California. This book gives an admirable presentation of the flora of the southwestern part of the country. The species are well delineated and illustrated, and brief but valuable data are given on the ecology of the different zones and the habitat favorable to each species. It follows the International Rules of nomenclature.

"Illustrated Flora of the Pacific States."—By Le Roy Abrams, Stanford University. First edition, Volume I, 1926, 557 pages and 1,299 illustrations. Volumes II and III to be issued. Stanford University Press. This work is patterned after the "Illustrated Flora" of Britton and Brown. When complete it should serve the same useful purpose for the western part of the United States that Britton and Brown's work has done for the eastern and central.

"Flora of Southeastern Washington and Adjacent Idaho."—By Charles V. Piper and R. Kent Beattie, Washington State College. First edition 1914, 296 pages, unillustrated; published by the authors.

"Flora of the Northwest Coast."—By Charles V. Piper and R. Kent Beattie, Washington State College. First edition, 418

pages, unillustrated; published by the authors. There is need for a manual covering the northwestern region of Washington, Oregon, Idaho, and that part of Montana that lies west of the Continental Divide, and these two by Piper and Beattie taken together come the nearest of any to filling the gap. They are conservative in the matter of dividing families, genera, and species, and follow the usual plan of keys and descriptions.

TAXONOMIC TREATMENT OF LIMITED GROUPS

A considerable number of books and papers have been written in restricted fields of taxonomy, sometimes taking the form of monographs of certain natural groups—genera, families, etc.—and sometimes presenting such miscellaneous groups as appeal to certain classes of readers—trees, flowers, edible plants, etc.

"The Silva of North America."—By Charles S. Sargent, Arnold Arboretum, Harvard University. First edition 1891, 14 volumes containing 2,185 pages and 740 splendid, full-page lithographic plates; Houghton Mifflin and Company. Sargent's *Silva* is one of the finest pieces of work produced in this country. The trees are considered by families, with some attention to the inter-relationships of genera and species. The synonymy of the specific names is given, with excellent descriptions of each species, and information on ecology and economic importance. The illustrations with their fine details are unsurpassed.

"Manual of the Trees of North America."—By Charles S. Sargent, Arnold Arboretum, Harvard University. Second edition, 1922, 910 pages and 783 illustrations; Houghton Mifflin and Company. Since its first appearance this work has been the standard condensed reference book on the trees and shrubs of this country. It describes both native and introduced species, following the Engler and Prantl arrangement and the International Rules of nomenclature.

"Winter Botany."—By William Trelease, University of Illinois. Second edition, 1925, 396 pages and over 300 illustrations; published by the author. The book is of convenient pocket size, and, while semipopular, it is highly authoritative. It contains analytical keys and excellent descriptions of most of the trees, shrubs, and woody vines in their winter condition. It is excellent for the use of students and the better-informed amateur botanists.

"Trees and Shrubs. Yellowstone National Park."—By Pliny H. Hawkins. First edition 1924, 125 pages and 24 illustrations; published by the author, Absarokee, Montana. This little handbook gives excellent, accurate, semipopular descriptions of the woody plants in the great National Park, their appearance, habitat, and significance. It is usable by visiting tourists and by all interested in the botany of the region.

"Monocotyledons."—By Mrs. Agnes Arber, Balfour Laboratory, Cambridge, England. First edition, 1925, 258 pages and 160 illustrations; Cambridge University Press. A well-rounded, thorough discussion of the morphology and affinities of the group. While the work is not primarily taxonomic it contains much information upon which the taxonomy of this great group must be based. It is a fine example of this type of monograph.

"The Phylogenetic Method in Taxonomy; The North American Species of *Artemisia*, *Chrysothamnus*, and *Atriplex*."—By Harvey M. Hall and Frederic E. Clements, Carnegie Institution. First edition, 1923, 355 pages, 47 text figures and 58 plates. Publication No. 3564; The Carnegie Institution, Washington, D. C. Following an introduction of 30 pages on general principles of taxonomy, the three genera mentioned in the title are discussed. The method of treatment of the three genera is similar. The characters or criteria used for subdivision are described, the affinities of the genera with related genera are discussed, and the internal relationships are shown by diagrams. Each genus is divided into sections, and these into species. What is more striking, each species has been studied with reference to its recognizable varieties, which are few in some species and many in others—the more plastic ones. These subspecies are designated trinomially. It is inevitable that where such fine subdivisions are recognized and expressed in phylogenetic diagrams there will be some differences in opinion among the critics, but these two workers have indicated ideals that others could well follow in monographing generic and other groups.

"Revision of North American Species of *Astragalus*."—By Marcus E. Jones. First edition, 1923, 330 pages and 78 pages of illustrations; published by the author, Salt Lake City, Utah. The author, having given a quarter of a century to intensive study of the genus in field and laboratory, pronounces it the most difficult of North American genera. After a spicily review of previous work on the group, he enters into a profound discussion

of its morphology, ecology, and taxonomy. Although recognizing some 1,500 species, 273 of which are American, he rejects all suggestions of dividing the genus, on the ground that relationships rather than size should determine the scope of a genus. He, therefore, groups the species into 29 subgenera or sections, the relationships of which are indicated in a diagram of genetic relationships. A considerable number of new species are proposed, and a few varieties are given recognition. The monograph will do much to clarify our knowledge of this genus.

CULTIVATED PLANTS

Most descriptive manuals or floras of the different regions do not include introduced species that are under cultivation unless they have escaped and become established with the native flora. The identification and study of the cultivated plants has been facilitated by a few important works.

"Origin of Cultivated Plants." By A. P. DeCandolle, Academy of Science of the Institute of France. First edition, 1882, 468 pages, unillustrated; D. Appleton and Co. Following a discussion of some thirty pages on the character of the evidence applicable to such a discussion, the author traces many varieties and species grown in different parts of the world back to ancestral forms growing wild. While considerable evidence has been brought out since the book was written concerning the origin of certain crop plants, most of the conclusions still hold.

"Field, Forest, and Garden Botany."—By Asa Gray, Harvard University. Second edition, revised and extended by L. H. Bailey in 1895, 549 pages, unillustrated; American Book Company. The emphasis in this book is on cultivated plants, although many native species are included. Keys, descriptions, and nomenclature conform to the contemporary edition of its companion, *"Gray's Manual."* For a half-century it was practically the only book available for the identification of cultivated plants and served its purpose well.

"Studies on the Origin of Cultivated Plants."—By N. Vavilov, Leningrad. 108 pages, 6 illustrations and 7 distribution maps. Bul. 2 of Applied Botany and Plant-Breeding, Vol. XVI, 1926, Leningrad. This paper presents modern methods of determining the place of origin and ancestral forms from which cultivated plants have arisen. The older methods of comparing cultivated varieties with similar wild ones of the vicinity and of using archae-

ological records are not ignored, but to these are added what the author designates as the "botanical method," which includes genetic and cytological evidences, and lays especial stress on the hypothesis that around the point of origin of a species much minor variation will be found among the individual plants, while in other regions to which it has spread there is greater uniformity. Evidence is also shown that certain species once regarded as weeds were later domesticated.

"Manual of Cultivated Plants."—By L. H. Bailey, Cornell University. First edition, 1924, 851 pages and 14 illustrations; The Macmillan Company. The book contains in compact form analytical keys and descriptions of most species and many varieties of plants that are cultivated in the United States for use or pleasure. It is up to date in its taxonomy and nomenclature, and gives some information concerning the origin of many of the forms treated.

"Official Code of Standardized Plant Names."—By F. L. Olmsted, F. V. Coville, and H. P. Kelsey, representing a joint committee of botanists and horticulturalists on the nomenclature of cultivated plants. First edition, 1923, 546 pages, unillustrated. Published by the committee, H. P. Kelsey Sec., Salem, Mass. This book is the expression of a very worthy attempt to secure greater uniformity of usage in the common and botanical names of cultivated plants, especially those offered for sale by nurserymen and seedsmen. The names are arranged in one alphabetical list, making use of different kinds of type to distinguish common names, botanical names, and synonyms.

"Botany of Crop Plants."—By W. W. Robbins, University of California. Second edition, 1924, 674 pages and 263 illustrations; P. Blakiston's Son and Company. The first fourth of the book is devoted to a discussion of the general morphology of flowering plants. In part two 21 families of especial economic importance are treated in detail, with emphasis on the morphology and uses of their most important members. The illustrations are unusually well planned and executed.

"Manual of Trees and Shrubs Hardy in North America."—By Alfred Rehder, Arnold Arboretum, Harvard University. First edition, 1927, 930 pages, unillustrated; The Macmillan Company. This book classifies and describes more than 2,300 species of woody plants with numerous varieties and hybrids, and gives distribution zones and notes on adaptability.

NON-TECHNICAL BOOKS

The phase of botany that most appeals to the amateur is the recognition and naming of the wild flora. Few amateurs give attention to any other branch of botany, while thousands seek to learn the names of at least the most conspicuous plants. Some amateur systematists take up the subject in the most superficial way, being content with almost any common name that they learn by word of mouth and never really examining plants at all, while others become remarkably proficient in all but the most difficult groups.

To aid the worthy attempts of those who seek to learn the names of the wild plants for their own pleasure a considerable number of books have been written. Such a task is by no means easy, and most such books have not been very successful. Various devices have been employed to aid the layman in identification work. General descriptions alone are almost total failures. Technical descriptions discourage all but the most determined. Semipopular keys are quite valuable to the more studious amateurs, and lead naturally to semipopular descriptions which are sufficient for species that are clear cut and few in a genus. Illustrations are being more and more used and are valuable to supplement keys and descriptions. They have some weaknesses. Good illustrations are so expensive that only a small percentage of the species can be honored by them. Furthermore many species are so much alike in general appearance that a given picture may apply equally well to several of them. This is especially true of the grasses. There is no convenient way of associating the plant in question with its picture in a profusely illustrated work, except by keys, hence the superficial worker spends much time rambling through the book hunting for the right illustration. There is no easy road to success in identifying plants, and all who expect to become proficient must master the morphology and terminology required to use technical manuals. It has been observed that the amateur who has not the courage to learn generic and specific botanical names lacks also the persistence required to determine them.

To simplify the work of identification, popular floras are usually restricted geographically and treat only the more conspicuous species, hence many plants will be collected that have been omitted from the book.

"Field Book of American Wild Flowers."—By F. Schuyler Mathews. Revised edition, 1912, 587 pages, 24 colored plates and more than 300 line drawings; G. P. Putnam's Sons. For the eastern half of the United States this book serves as a good guide for the amateur. The plants are arranged by families, and most of the prominent species are described and illustrated. Two keys facilitate the association of the specimen with its description, a color key, and a key based on the more obvious morphological characters. Both common and botanical names are given, the latter following the International Rules.

"Rocky Mountain Flowers."—By F. E. Clements and Edith S. Clements, Carnegie Institution. First edition, 1914, reprinted in 1920, 392 pages and 47 plates, more than half of which are colored; The H. W. Wilson Company, New York. The presentation is semipopular, with numerous keys and fine illustrations. Families and genera are described, and some of the species are listed but not described. The distinctive feature of the work is a flower chart which aids in the location of families by lines and formulae that indicate different types of floral structure. Some skill is required to use this chart but it is very helpful when mastered.

"Wild Flowers of the North American Mountains."—By Mrs. Julia Henshaw, Alpine Club of Canada. First edition, 1915, 383 pages and 83 plates, a fourth of which are colored; Robert M. McBride & Company, New York. The book is particularly applicable to Canada and the northern United States. The key is not of an analytical type, being merely a synopsis, but as a device for aiding the reader in placing his specimen the plants are grouped according to flower colors, a method which in most cases narrows the search down to a point where the desired picture can be found with some readiness. The illustrations are excellent and both technical and popular descriptions are given, with a liberal admixture of sentiment.

PALEOBOTANY

Paleobotany holds the joint interest of geologists, botanists, and zoologists, because of its record of conditions on the earth during past ages. Not only does it shed much light on the phylogenetic relationships of plants, but it indicates in many cases the climatic and other environmental conditions under which the development of the plant and animal kingdoms, including man, took place.

"Studies in Fossil Botany."—By D. H. Scott, Royal Botanic Gardens, Kew, England. Third Edition, 1920, two volumes containing 880 pages and 326 illustrations; A. and C. Black, Ltd., London. Volume I covers the pteridophytes and lower plants and Volume II the higher plants. We have here an authoritative treatment of the subject by a veteran writer. Not only are the paleontological findings recorded and summarized, but philosophical discussions on evolutionary relationships are presented. While the evidences used are obtained chiefly from the rocks, the morphology of existing plants has not been ignored.

"The Origin of a Land Flora."—By F. O. Bower, University of Glasgow. First edition, 1908, 727 pages and 261 illustrations; Macmillan and Co., Ltd., London. The author here presents an hypothesis concerning the origin of the higher plants and the part played by the presence of land above the waters that had long covered it. In presenting his evidences the author has assembled data of much value aside from their bearing on the topic of the book.

"Paleobotany: A Sketch of the Origin and Evolution of Floras."—By Edward W. Berry, Johns Hopkins University. 119 pages and 42 illustrations; *Ann. Rept. Smithsonian Institution*, 1918. A concise account, suitable to the needs of botanical students, summarizing our knowledge of fossil plants, especially the pteridophytes and spermatophytes. Valuable diagrams are given on the prevalence of different groups during past epochs.

"Plants of the Past; a Popular Account of Fossil Plants."—By Frank H. Knowlton, U. S. Geological Survey, First edition, 1927, 275 pages and 90 illustrations; Princeton University Press. This book, from an authoritative source, gives the general reader a clear idea of plants that have existed on the earth at different geological periods and the reasons for changes in flora. It also has chapters on the importance of plants to prehistoric animals, and on coal production.

"Tree Ancestors."—By Edward W. Berry, Johns Hopkins University. First edition, 1923, 270 pages and 48 illustrations and maps; The Williams and Wilkins Company. A discussion of the past and present status of some of the most important families of woody plants, presenting valuable information in a most readable style. The book gives clear-cut explanations of the peculiar distribution of many species, the survivors in favored localities of once cosmopolitan races.

INDEXES, CATALOGS, ETC.

From time to time works have been written summarizing the advancement that has been made in the study of plants. These are of especial value in locating the literature on different phases of the subject.

"Thesaurus Literaturae Botanicae."—By G. A. Pritzel, Berlin. Second edition, 1872, 254 pages, unillustrated; F. A. Brockhaus, Leipzig. The chief botanical publications up to 1872 are listed under the names of the authors, arranged alphabetically, and in a later section classified by subjects. About 15,000 references are listed.

"Guide to the Literature of Botany."—By B. D. Jackson, Linnaean Society, London. First edition, 1881, 626 pages, unillustrated; Longmans, Green and Co. A very large, classified list of works on botanical subjects in various languages, probably the most complete that has been published for the time up to 1881. Generally each reference includes the author, title, and place of publication, and the ones the author considers noteworthy are starred.

"Genera Siphonogarum."—By C. G. De Dalle Torre and H. Harms, Berlin. First edition, 1907, 921 pages, unillustrated. This is a valuable aid in the tracing of generic synonymy. Following a list of families of spermatophytes some 637 pages are devoted to lists of genera, arranged by families and subfamilies, and showing the sections of the genera, if such occur. The synonymous names of genera and sections are given, with dates and citations. The last part of the book is taken up by a huge index of 284 pages containing all the generic and sectional names used in the text. The work follows the Engler system.

"Index Kewensis."—By B. D. Jackson, Kew Herbarium, under the direction of Jos. D. Hooker. The original work (1893 to 1895) consisted of four large volumes having a total of 2,567 pages, unillustrated, and to these have been added six large supplements; Cambridge University Press. This monumental work lists all species described since 1753 under their genera, which are arranged alphabetically, and each specific name is accompanied by a reference to the original publication. Invalid synonyms are in italics and referred to the accepted name. It is indispensable to the research worker in taxonomy of flowering plants.

MISCELLANEOUS

The simple grouping used in this chapter for the literature of systematic botany leaves some important publications unclassified.

"A Glossary of Botanical Terms."—By B. D. Jackson, Linnaean Society of London. Third edition, 1916, 428 pages, unillustrated; J. B. Lippincot Co. Most manuals include glossaries of the terms used, and in most circumstances these are sufficient for the purpose intended. Many technical terms used in botanical science are not, however, included in these limited lists. Furthermore some terms require a fuller discussion than space will permit in connection with a crowded manual. This book fills the needs just indicated in an admirable way.

"Outlines of the History of Botany."—By R. J. Harvey-Gibson, University of Liverpool. First edition, 1919, 274 pages, unillustrated; A. and C. Black, Ltd., London. A well-balanced discussion of the development of botanical science, including especially its taxonomic, morphological, and physiological aspects. It is authoritative, unprejudiced, and executed in a style well suited to student use.

"Native American Forage Plants."—By Arthur W. Sampson, University of California. First edition, 1924, 435 pages and 200 illustrations; John Wiley and Sons, Inc. The subject is treated with especial reference to the Rocky Mountain and Pacific regions, but applies in a measure to the entire country. The treatment is particularly effective and convenient. The plants are grouped by families, and the more important species are clearly described. Valuable information is given concerning their distribution, abundance, palatability, and nutritive value. Summary tables facilitate the finding of desired information.

"American Honey Plants."—By Frank C. Pellett. Second edition, 1923, 392 pages and 194 illustrations; published by *The American Bee Journal*, Hamilton, Ill. The subject is treated in a semipopular way, although botanical names of the plants are given. A large number of plants are described, with information concerning their distribution, the amount and quality of honey produced, and conditions favoring nectar secretion.

"Useful Wild Plants of the United States and Canada."—By Charles F. Saunders. First edition, 1920, 275 pages and 74 illustrations; Robert M. McBride & Company, New York. This book is written in semipopular style, using both common

and botanical names. It summarizes our knowledge of the past and present use of plants by the Indians and the white men that followed them. In addition to assembling the knowledge acquired by others, the author adds many of his own observations. Special emphasis is laid on the use of plants for food, but medicinal and other properties are considered also.

"Manual of Weeds."—By Ada Georgia, Cornell University. First edition, 1914, 593 pages and 385 illustrations; The Macmillan Company. Following a chapter on the fundamental principles of weed development, dissemination, and control, several hundred weed species are described and discussed. The arrangement is by families, and both common and botanical names are given. Under each species is given the source, means of propagation, season of development, distribution, and habitat. The methods of control are briefly indicated.

PART II
FAMILIES OF SPERMATOPHYTA

CHAPTER XI

GENERAL FEATURES OF SPERMATOPHYTA

The spermatophyta¹ or seed-bearing plants have formed the most conspicuous part of the vegetation of the earth for millions of years, since the middle of the Paleozoic era (see frontispiece). From the time of their origin their superiority over other plants in fitness to inhabit the land asserted itself, and their increase in numbers, size, and diversity of form was rapid.

The best known of the Spermatophyta are the conifers and flowering plants. There are some differences in the use of the term "flower." Some would restrict it to the usually showy reproductive and accessory organs found in the angiosperms, while others would include under it the strobili of the gymnosperms. The situation is further confused by the use of the term "ament" to indicate in the angiosperms a certain kind of inflorescence (catkin), and in the gymnosperms a strobilus which by some is regarded as an inflorescence and by others as a flower.

Most of the seed plants are autophytic, *i.e.*, possessed of chlorophyll and therefore not dependent on organized material for nutrition. A few, however, are saprophytic or parasitic, to a greater or less degree, and a few have adopted an epiphytic habit. The great majority are terrestrial, but here and there throughout the group members have invaded shallow waters and become adapted to an aquatic life.

This is by far the largest of the four divisions of the plant kingdom, and contains upwards of 130,000 species. These are grouped into some 300 families, of which approximately two-thirds are represented in the United States. The number of families cannot be stated exactly, for authorities differ as to what constitutes a family in certain cases. In some systems of classification such families as Liliaceae, Rosaceae, Leguminosae,

¹ The author would prefer to avoid the divisional name Spermatophyta as it includes several distinct phyla, some of which appear to be more closely related to the ferns than to each other. To avoid confusion with the manuals, however, the term will be used with this explanation.

and Compositae, including large numbers of genera, are preserved, while in other systems each of these is broken up into two or more smaller families. In any event it is beyond the scope of a beginner's textbook to deal adequately with all these families, and the student can best familiarize himself first with a limited number carefully selected from different parts of this great group of plants, and later extend his knowledge by more advanced study. To this end sixty families have been selected for discussion here. Some are chosen because of the large number of species which they contain; others because of their economic importance; while a few, not so common nor so important, have interesting peculiarities equally worthy of attention. All of those treated here are found in the United States, and most of them are widely distributed elsewhere.

The sequence in which these families are taken up is essentially that found in Engler and Prantl's "*Natürliche Pflanzenfamilien*," and in modern systems of classification the sequence is supposed to give some indication of phylogenetic relationships. Even though the Engler and Prantl system be wrong in its placing of the monocotyledons and the "*amentiferae*" before the other dicotyledons, as discussed on page 45, it seems best to follow it here for the most part since most of the manuals in this country do so, and to attempt to use two systems simultaneously is confusing.

No attempt is made here to group the families into orders for two reasons. In the first place, many of the orders of the angiosperms are not clear-cut phylogenetic entities, but are loosely and perhaps artificially associated families. As previously stated, most of our descriptive manuals of flowering plants either ignore the orders or name them without description. In the second place, a discussion of only sixty selected families would fail to bring out the significance of the orders even if it were well established.

CLASSIFICATION OF SEED PLANTS

To show the relationships of the families in the larger subdivisions of the seed plants, the following synopsis of classification is submitted.

DIVISION SPERMATOPHYTES

Plants with true roots, stems, and leaves which belong to the sporophyte generation, the gametophytes being reduced to very

small size. Reproduction is by seeds, sometimes supplemented by vegetative propagation.

CLASS I. GYMNOSPERMAE

Strobili unisexual or bisexual, the female producing naked ovules, *i.e.*, ovules and resulting seeds not enclosed in carpels. Vascular bundles collateral and arranged in a cylinder about a pith. The xylem region contains tracheids but no tracheae (excepting in the Gnetales).¹ The female gametophyte (except in Gnetales) is multicellular and contains several archegonia. The male gametophyte is very much reduced. In the more primitive forms (*Cycas* and *Ginkgo*) it produces motile gametes, but in the higher ones these are non-motile cells.

CLASS II. ANGIOSPERMAE

Plants with true flowers, each containing, normally, four whorls of floral organs. Ovules enclosed in carpels which may be distinct or united into a compound pistil. Vascular bundles collateral, and arranged either in a cylinder surrounding a pith or scattered through the pith. The xylem region contains fibers and tracheae. The female gametophyte produces no archegonia and is reduced to eight cells (or to one cell with eight nuclei). The male gametophyte is the germinated pollen grain, usually with three non-motile cells.

Sub-class 1. Dicotyledonae.—Floral parts usually in multiples of five or four. Two cotyledons in each seed (rarely one). Vascular bundles usually in a cylinder with a cambium separating phloem and xylem. Leaves with netted veins.

Sub-class 2. Monocotyledonae.—Floral parts usually in multiples of three. One cotyledon in each seed, often with the rudiment of another. Vascular bundles usually scattered through the pith and without cambium. Leaves with parallel veins (rarely netted).

¹ In the Gnetales characters are found strikingly different from those of other gymnosperms: (1) secondary xylem containing tracheae; (2) female gametophytes so reduced that they contain no archegonia; (3) wood without resin ducts; (4) compound unisexual strobili; and (5) dicotyledonous embryos. No one species of the order has all these characters, but all are well represented within the group. Because of these characters, the Gnetales have variously been considered: (1) angiosperms, (2) a connecting link between the other gymnosperms and the angiosperms, (3) offshoots from the same stock that produced the angiosperms, and (4) of different stock from the angiosperms but expressions of the same evolutionary tendencies as those that resulted in the angiosperms (convergent development).

CHAPTER XII

FAMILIES OF GYMNOSPERMS

The gymnosperms consist mostly of trees and shrubs, some of gigantic size. They were once the predominant vegetation of the earth, but have long been gradually declining in numbers (see frontispiece). They are of ancient lineage, perhaps as far back as Cambrian times, but reached the climax of their abundance in the Pennsylvanian (Upper Carboniferous) period, since which time they have been on the wane.

The origin of the gymnosperms presents a difficult problem. Coulter and Chamberlain¹ recognize seven orders: (1) Cycadofilicales (Pteridospermae), the most ancient of known forms and now extinct; (2) Bennettitales, mostly Mesozoic and now extinct; (3) Cycadales, probably never dominant but still surviving; (4) Cordaitales, occurring with Cycadofilicales and now extinct; (5) Ginkgoales, fairly abundant during the Mesozoic era, now represented by only one living species; (6) Coniferales, abundant since the latter part of the Paleozoic era, and far more common now than all other gymnosperms combined; and (7) Gnetales, of unknown antiquity and now represented by only three genera and about fifty species. For many years it was supposed that the gymnosperms were a monophyletic group originating from one group of pteridophytes. There is a growing belief, however, that they are a polyphyletic group, and that the Cycadales and the Coniferales, at least, arose from different ancestral pteridophytes. This belief finds its evidence not only in comparative morphology and paleobotany, but in serum diagnosis (see page 52).

The best-known of the gymnosperms are the Coniferales (Pinales), which form almost the exclusive forest type in many cold semi-arid regions. Some authorities include the three families here described as Pinaceae, Taxodiaceae, and Cupressaceae, under the one family name Pinaceae.

¹ "Morphology of Gymnosperms," University of Chicago Press, 1910.

1. PINACEAE. Pine Family

A very important family of cone bearing, mostly evergreen trees, containing about 8 genera and 150 species. They are of world-wide distribution, extending even to lofty mountain sides and far into northern regions. The Pinaceae were more abundant during the later Cenozoic era (see p. 9) than now, but they have held their own better than most of the gymnosperms, probably because of their greater adaptability to the cold dry climates that in most parts of the temperate zones replaced the subtropical conditions which prevailed before the Glacial epoch. The Pinaceae and other conifers may be looked upon as the highest evolutionary development of the gymnosperms. Even so they doubtless are not the direct ancestors of the angiosperms but rather a somewhat specialized side branch of the main genetic line.

Familiar Examples.—Familiar examples of the pine family are pine (*Pinus* spp.), hemlock (*Tsuga* spp.), fir (*Abies* spp.), spruce (*Picea* spp.), and larch or tamarack (*Larix* spp.).

Stems and Roots.—The Pinaceae are all woody and are for the most part stately trees with straight, slightly tapering trunks, sometimes more than 250 feet high and 10 feet in diameter. The root system is generally wide-spread but not deep. The wood of the Pinaceae, like that of most gymnosperms (excepting Gnetales), differs from that of angiosperms in lacking tracheal vessels, their place being taken by tracheids. All parts of the tree contain intercellular resin ducts, which become non-functional in the old heart wood.

Leaves.—The Pinaceae all have rather thick, linear, alternate leaves. In the pines they are $1\frac{1}{2}$ to 12 inches long, but in the other genera they are shorter. This reduced leaf surface combined with a sunken condition of the stomata results in low transpiration, and the trees are thus able to survive in dry or frozen soils. With the exception of the larches or tamaracks the Pinaceae are evergreens, that is, they are clothed with foliage the year round. Each leaf persists on the tree from three to ten years, depending on the species, but ultimately falls off. In addition to the regular foliage leaves the pines have scales, sometimes called primary leaves, on the buds and young shoots. These are relatively broad and thin, and deciduous. In the pines the leaf bases are enclosed in sheaths—one, two, three, four, or five leaves (depending on the species) growing from each

sheath. In the other genera the leaves are single. The ever-green species have leaves of a very dark green, giving a somber appearance to the forests which they compose.

Strobili.—All members of this family are heterosporous, producing microspores in male strobili and macrospores in female strobili, both borne on the same tree. In the male strobili pollen sacs are borne on the under side of each scale, and in the female strobili two ovules are borne on top of each scale.

Seeds.—The seeds mature in one-half to three and one-half years after fertilization. They are produced in large woody cones that open to release them. In most species each seed bears a broad wing which causes it to spin around in falling and so delays its descent that even a light wind will carry it to a considerable distance. The seed contains a relatively large endosperm and a straight embryo.

Economic Significance.—The Pinaceae are of great importance to mankind. But for this family of trees our familiar frame buildings could hardly exist. Pine, fir, spruce, and hemlock are not only more abundant than other kinds of lumber, but they are easy to work and do not warp badly when exposed to the weather. The turpentine which is an essential ingredient of ordinary paint and the rosin of varnish are extracted chiefly from pine stumps. The wood of this family is not of the highest grade for fuel, but because of its abundance in many regions where the hardwoods are lacking it is a great asset and is extensively used. Lastly, the forests of pine and other conifers cover many dry rugged mountain sides that would be desolate without them, and thus conserve the moisture and beautify the landscape. Where mixed with the light-green, broad-leaved forest trees the darker colors of this family give a most pleasing effect.

2. TAXODIACEAE. *Taxodium* Family

This family, once one of the most conspicuous on earth, is now reduced to 8 genera, nearly extinct in the United States, and widely scattered over the rest of the world. They are adapted to warm moist climates, and throughout most of the Cenozoic era, especially the Miocene epoch, in the balmy climate that generally prevailed, their gigantic forms covered almost the entire northern hemisphere with a few extensions into the southern.

Familiar Examples.—The Taxodiaceae are rare in the United States, being confined to two species of *Sequoia*, the big trees (*S.*

gigantea (Lindl.) Deene.) and the redwood (*S. sempervirens* (Lamb.) Endl.) of California and Oregon, and two species of *Taxodium*, bald cypress (*T. distichum* (L.) L. C. Rich.) and pond cypress (*T. ascendens* Brongn.) of the southeastern states (not to be confused with the cypresses of the family Cupressaceae).

Stems and Roots.—The few remaining species of this family are trees, the best known of which are the *Sequoias* of California. Some of these are 350 to 400 feet high, and 20 to 30 feet in diameter—the largest forms of life the earth has ever known. The largest *Sequoias* are estimated to be nearly 4,000 years old, having spent half their life time before the birth of Christ. A wondrous record of alternating prosperity and famine, as drought succeeded favorable climatic conditions, can be read in the varying widths of their annual rings. The growth of anchor roots, going on for centuries under so great a weight, has resulted in huge, gnarled buttresses at the surface of the ground.

Leaves.—The leaves are linear or scale-like and alternate.

Strobili.—Both male and female strobili are borne on the same tree. There are several pollen sacs on the under side of each staminate scale and several ovules on the upper side of each ovuliferous scale. The female strobili develop into woody seed-bearing cones.

Seeds.—The seeds mature either the same season or the second season following fertilization. There are three to seven on each scale. A narrow wing extends as a margin all around each seed in *Sequoia*, but is absent from the triangular seeds of *Taxodium*.

Economic Significance.—Were the trees of this family as abundant as those of Pinaceae their value would be almost incalculable. Unfortunately they are restricted to a small area. The redwood of California and its sister species, the big tree, furnish lumber of unusual quality. It is reddish in color (except the sap wood which is nearly white), evenly grained, light in weight, but rather strong though brittle—especially that of the big tree. It is rich in tannic acid and resists decay better than the woods of the Pinaceae. There is, however, well-grounded sentiment against cutting these trees, for they are the last of the noblest race of trees the earth has produced. Furthermore, these great trees when cut shatter almost like glass and the waste is enormous—sometimes sixty to ninety per cent.

The bald cypress (*Taxodium*) is less restricted in its range than the *Sequoias*, being found in the swampy regions of a dozen

of the southeastern states. Its habitat protects it somewhat from the woodman's axe, but it is slowly disappearing. The wood is of unusual quality, being heavier, harder, and stronger than that of the redwood and resisting decay even better. It is greatly sought for structural work in contact with the soil, where decay is most destructive, for greenhouse work, for staves, and indeed for a wide range of uses. In comparison with the *Sequoias* of the Pacific coast, little effort is being made to conserve it.



FIG. 12.—*Taxodium* (Taxodiaceae) showing natural habitat in swamp. The "knees" are formed by angles of the roots projecting above the mud and water. (After Bergen and Caldwell.)

3. CUPRESSACEAE. Cypress Family

The family Cupressaceae is rather small, containing but 10 genera, widely distributed over both hemispheres.

Familiar Examples.—The commonest examples of the Cupressaceae are the cedars (*Thuja* and *Juniperus* spp.), junipers (*Juniperus* spp.), arbor vitae (*Thuja* spp.), and cypresses (*Cupressus* sp.), but not the bald cypress (*Taxodium distichum* (L.) L. C. Rich.), which belongs to the Taxodiaceae.

Stems and Roots.—Many of the Cupressaceae are handsome shrubs, and some are large forest trees, the giant cedar reaching a height of 200 feet and a diameter of 15 feet. The tissues are resinous and in most species aromatic.

Leaves.—The leaves are small and linear, or, more often, scale-like and closely covering the twigs. They are evergreen, persisting usually from three to five years. They have an opposite or whorled arrangement on the stem, in which respect they differ from those of the Pinaceae and Taxodiaceae.

Strobili.—Some members are monoecious and others dioecious. The scales are few in number, each bearing several pollen sacs or one to many ovules. In most genera the ovuliferous strobili develop into small woody cones but in *Juniperus* the scales fuse into round, blue or reddish fleshy bodies commonly called berries.

Seeds.—In the dry woody cones the seeds generally produce narrow marginal wings. In the fleshy "berries" there are one to six seeds, which are wingless and usually angled.

Economic Significance.—The largest member of the family, the giant cedar (*Thuja plicata* D. Don), is a splendid forest tree growing extensively on the Pacific Coast from Alaska to California. The others are smaller trees or shrubs. In general the wood is light in weight, soft and easily worked, but very durable. It is, therefore, extensively used for shingles, fence posts, poles, ties, bridge work, and boats. Special uses are for cedar chests, where the aromatic wood acts as a repellent to moths, and for lead pencils, which require a soft, smooth-grained wood. Cedar-wood oil is extracted for technical purposes.

Several of the smaller trees and shrubs are grown for ornamental purposes, but the red cedar (*Juniperus virginiana* L.), found extensively in the eastern United States, is an alternate host for the apple-rust fungus, and is being replaced by other species that do not have this objectionable feature.

CHAPTER XIII

FAMILIES OF DICOTYLEDONS

The dicotyledons are generally considered the larger, the more important, the more ancient, and yet the more highly developed of the two subclasses of angiosperms.

Origin.—That the first dicotyledons appeared in the early Mesozoic era, or perhaps the late Paleozoic is generally conceded (see frontispiece). The oldest known fossils of this group are from the lower Cretaceous rocks, but they show a degree of advancement that seems to justify us in believing that they had a long line of ancestors whose remains have not yet been found.

It is pretty generally agreed that the dicotyledons came from gymnosperms of a type somewhat different from any existing forms. The anatomy and histology of the stem, the spore formation, and the morphology of male and female gametophytes are all in harmony with this belief, if we make due allowance for advancement in structure by both gymnosperms and dicotyledons since the time when the former gave origin to the latter. In all likelihood both groups were considerably different at that time from any existing forms; and an attempt to trace the connection through species now living or through a fragmentary fossil record is admittedly a treacherous undertaking. Some of the similarities noted may represent only parallel, or in some respects convergent, development of the two groups.

There are two general beliefs regarding the groups of gymnosperms on the one hand and of dicotyledons on the other that represent the genetic connection. Some hold the view that primitive Gnetales gave rise to primitive "Amentiferae," now represented by willows, birches, etc. On this hypothesis the unisexual strobilus of the Gnetales is equivalent to the ament of the Amentiferae, the apetalous unisexual flower of the latter being primitively simple rather than simple by reduction. The Engler and Prantl system embodies this supposition. Others maintain that the primitive Bennettitales or perhaps Cycadales

gave rise to a simple form of Ranales represented today by the Magnoliaceae, Ranunculaceae, etc. According to this belief the bisexual strobilus is homologous with a bisexual symmetrical flower, the petals and sepals originating by a sterilization of the lower sporophylls. The system of Bessey is in harmony with this line of reasoning, which further maintains that apetalous and unisexual flowers have become so through a process of simplification.

Description.—The dicotyledons have some families entirely woody and others entirely herbaceous, but in most of the families both woody and herbaceous members can be found. Each seed contains two cotyledons which may or may not rise above the ground during germination. In rare instances one cotyledon is absorbed in embryonic development, or more than two are formed. The fibrovascular bundles are characteristically arranged in a hollow cylinder, similar to that in the gymnosperms, with a cambium layer separating the tissues into bark and wood, and forming annual rings of growth. The center is occupied by a pith which is never large and may be very tiny. With few exceptions the vascular bundles in the leaves form branched or netted veins. Dicotyledons are usually deciduous, the exceptions being a few evergreen shrubs and trees, probably derived from deciduous ancestors. In regions where the climate is uniform throughout the year, *i.e.*, not divided into winter and summer or wet and dry, the distinction between deciduous and evergreen leaves is not obvious.

4. SALICACEAE. Willow Family

The Salicaceae contain but two genera—*Populus*, with about 30 species and several horticultural varieties, and *Salix* with over 160 species and many hybrids which make some sections of the genus difficult to classify. The family is a distinctly northern one, for, while representatives of both genera are found in the subtropics and even in the tropics, they are more numerous farther north and some species are found beyond the arctic circle and at the edges of glaciers high up in the mountains.

The race is an ancient one, both willow and poplar fossils being found in Cretaceous rocks. They were abundant throughout the Cenozoic era and withstood the glacial invasion of the Pleistocene epoch better than did most trees.

Familiar Examples.—The willows (*Salix* spp.) and the poplars (*Populus* spp.), some of which are also called cottonwoods, are the only examples.

Stems and Roots.—The poplars are all trees, the large ones more than 100 feet high and 6 feet in diameter. Some of the willows are trees as tall as the poplars, though not quite as large in diameter, but most of them are shrubs, some of the arctic and alpine species being only a few inches high. In general the Salicaceae make a rapid growth but are short lived in comparison with the hardwood trees that make up the bulk of our deciduous forests.

Leaves.—The leaves are alternate and simple, with variously toothed margins and a shape varying from narrowly lanceolate in the willows to nearly circular in some of the poplars. Stipules are produced by nearly all species, but in some they are small and fugacious. In the willows the leaves are sessile or with short petioles, but in the poplars they have long petioles. The buds are large and scaly, and in certain species of *Populus* coated with a yellow, sticky aromatic secretion.

Inflorescences and Flowers.—All the family are dioecious (or by exception monoecious) with unisexual apetalous flowers borne in aments which appear in the spring in advance of the leaves. They are borne singly, as a rule, on the previous season's growth, in the axils of the leaf scars. On the willows the aments, especially the pistillate, tend to be erect, but on the poplars they are usually pendulous, especially the staminate.

The staminate aments vary in length from less than 1 inch in certain willows to 4 inches in some of the poplars. They produce many flowers, each subtended by a bract. Each flower consists simply of a small group of stamens set in a cup-shaped, often glandular disc. There is no recognizable perianth. Occasionally a bisexual flower or a pistillate flower develops in the staminate ament. The ament persists until the pollen is shed and then drops.

The pistillate ament contains many very simple pistillate flowers each of which is but a pistil in a concave disc without perianth. Each pistil is bicarpellate, with a short style and two to four stigmas. The ovules are numerous in a single chamber. Ordinarily the poplars are wind pollinated and the willows insect pollinated.

Fruits and Seeds.—The fruit is a small capsule dehiscing by two valves. The seeds are numerous, small, plumed, and without endosperm or nearly so. The embryo is straight. As soon as the seeds are all or nearly all discharged, the aments that produced them drop.

Economic Significance.—The Salicaceae are somewhat exacting in their ecological requirements. They must have sun, and yet they do not thrive in hot climates. With sufficient water they grow in almost any kind of soil. For these reasons their distribution is unique. Where other trees can grow these do not, except scatteringly along forest streams. Where other trees find conditions uncongenial, on the banks of prairie streams and in cold marshes, there we find poplars and willows. They are therefore a distinct addition to the total of woody flora. The vast prairie regions of the semi-arid west would be practically treeless but for the poplars.

The wood of the poplar is distinctly inferior in quality, but for fuel it is much better than no wood. It is little used for lumber, but the quaking aspen and some other species, because of their soft texture and whiteness, are extensively used for paper pulp, of which there is a shortage in this paper age. The willow wood is likewise of low grade for fuel, although it was formerly much used for charcoal. In strength, however, it is much superior to poplar, a fact which has given it some usefulness for cricket and baseball bats, implements, chairs, etc., where small pieces can be utilized. Its greatest use is for basketry where it has played a part since the dawn of civilization.

In many parts of the world where the finer shade trees thrive the poplars are regarded as inferior, but in many regions not so blest they are extensively planted for the shade and beauty which their rapid growth and dense foliage quickly provide. The plumes of the seed, commonly known as the "cotton" of cottonwoods, are so abundant in some species that they are distinctly objectionable. The trees are propagated by cuttings, and where these are taken from staminate trees only, this trouble is avoided.

The Salicaceae are not usually thought of as contributing much in the line of food, but in reality the shrubby willows furnish considerable browse for livestock in the mountainous regions of the west, and keep many deer and other wild animals from starvation when deep snows cover the grass. The poplars are said to furnish a supply of winter food for the beaver.

In sections where beekeeping is profitable the willows serve the very useful function of supplying early nectar for brood rearing before most other honey plants come into bloom.

5. JUGLANDACEAE. Walnut Family

In the Juglandaceae we have a small family of fine large trees. There are but 6 genera and 35 species. In all likelihood they are not genetically close to the other "Amentiferae," *e.g.*, the birches and the poplars.

Apparently the Juglandaceae were once more abundant than now. Their remains are found in Cretaceous rocks, and throughout the most of the Cenozoic era they were widely distributed over the northern hemisphere, with the exception of the arctic regions. The frigid climate that generally prevailed in the north temperate zone during the Pleistocene epoch exterminated them excepting in favored localities. Europe lost all of her hickories and nearly all of her walnuts, the survivors being restricted to the eastern Mediterranean region.

Familiar Examples.—Well-known examples of the Juglandaceae are walnuts (*Juglans nigra* L. and *J. regia* L.), butternut (*J. cinerea* L.), hickories (*Carya* spp.), and pecan (*Carya Pecan* Aschers. and Graebn.).

Stems and Roots.—The existing members of the Juglandaceae are all trees, often of considerable size. The pecan and the black walnut grow to a height of 150 feet and a diameter of 6 feet. When somewhat crowded they have straight, smooth trunks, the lower half free from branches. Standing alone they are widely branching and of striking appearance. The young bark is glandular and somewhat aromatic, and the pith in walnut and butternut is diaphragmed, *i.e.*, filled with thin, hard, horizontal partitions set at close intervals, in longitudinal section appearing like a ladder.

In most species two or three buds may be found above each leaf. The lowest is in the axil of the leaf, or slightly above, and the others are superposed in a row, with small intervals between. The buds are large and well protected by stout scales, which are often densely pubescent. The leaf scars are very large and conspicuous.

Leaves.—The leaves are odd-pinnately compound and very large in some species. In black walnut and butternut, which commonly have thirteen to nineteen leaflets, they are as much



FIG. 13.—*Juglans cinerea* (Juglandaceae). 1, branch with staminate and pistillate flowers. 2, leaflet. 3, staminate flower. 4, pistillate flower. 5, fruits. 6, twig. 7, longitudinal section of twig. 8, leaf scar and superposed buds. 9, nut with husk removed. 10 & 11, terminal buds. 12, lateral buds. (After Illick.)

as 2 feet long and very handsome. The leaflets vary from lanceolate to ovate, with finely serrate margins, and have a viscid aromatic pubescence, especially on the lower surface. The arrangement on the stem is alternate.

Inflorescences and Flowers.—The flowers in the Juglandaceae are unisexual, the staminate in pendulous aments, and the pistillate solitary or few in a group. Both kinds are borne on the same tree.

The staminate aments are borne just above the leaf scars of the previous season. They may be either single or in clusters of two or three, and are from 3 to 5 inches long. Each ament produces many staminate flowers. Each flower consists of a group of several pollen sacs, surrounded in most cases by a two- to six-lobed perianth. This flower is set in the axil of a bract with a small bracteole on either side. Occasionally a rudimentary pistil is borne in the staminate flower.

The pistillate flowers are borne at the tips of the twigs. Each consists of a bicarpellate pistil with a calyx of four lobes (sometimes three or five), and often with as many tiny petals. The ovary is inferior, or nearly so, with one ovule and two stigmatic styles. The pistillate flower, like the staminate, is set in the axil of a bract with two lateral bracteoles. It is not ready for fertilization until after the pollen is shed.

It will be noted that such flowers are far from primitive, but show a considerable degree of specialization.

Fruits and Seeds.—The fruit is a nut, or, in reality, a sort of dry drupe. The thick outer wall or husk is tough and leathery and in some species dehiscent. It appears to be formed by a fusion of bract, bracteoles, and perianth. The inner shell or pericarp is exceedingly hard. It consists of the matured ovary wall. The nut contains a single seed with two large, lobed, and convolute cotyledons, and no endosperm.

In certain genera, no longer found in the United States, notably *Engelhardtia*, the fruit is small, with large wings, a samara.

Economic Significance.—In proportion to the number of individuals the Juglandaceae are of great importance. The fruits of the walnut, butternut, pecan, and some species of hickory are very highly prized and grown in considerable abundance. The wood of black walnut is so desirable for furniture, interior finishing, etc., that it has been cut almost to extermination. It is rather dark, even grained, strong, easy to work, and holds its

shape well. The wood of the butternut is softer and weaker and yet of fair quality. In hickory we have one of the greatest of all woods for certain purposes. It is light in color, very close and even grained, and exceedingly strong, especially the second growth that has sprouted up from stumps and grown into small trees. No other wood can replace it where extreme toughness is required, as for hammer and axe handles, and spokes, shafts, tongues, and other parts of wagons. The wood of the pecan is intermediate in weight and strength between walnut and hickory. Unfortunately, the trees of this family have a very limited range. They are more abundant in the United States than elsewhere, but here they are found only irregularly in the eastern and south-eastern sections and on the Pacific Coast. The demand has greatly exceeded the supply with the results that one would expect.

Aside from their value for lumber and nuts, the walnut and butternut are highly desirable for ornamental trees, as their great spreading tops and magnificent foliage are hardly surpassed by any other trees.

6. BETULACEAE. Birch Family

The birches and their relatives are well known throughout the deciduous forest regions of the country. There are 6 genera and about 80 species found mostly in the north temperate zone but a few extending into the south temperate zone in the Andean region. The arctic birches of today are found as far north as any woody plants, but in the latitude of northern United States and central Europe they are at their best. Their earliest remains are from Cretaceous rocks, and throughout most of the Cenozoic era a considerable number of species flourished that are now extinct. On the whole, however, they held their own through the Glacial epoch better than did most plants.

Familiar Examples.—The best known of the Betulaceae are birches (*Betula* spp.), alders (*Alnus* spp.), and hazelnut and filbert (*Corylus* spp.).

Stems and Roots.—The Betulaceae are all woody, varying in size from the dwarf arctic birches to the yellow, black, and canoe birches which are sometimes more than 100 feet high and 4 feet in diameter. One of the conspicuous characters of the family is the periderm, the thin corky outside layer of the bark that in the



FIG. 14.—*Betula papyrifera* (Betulaceae). 1, branch with staminate and pistillate flowers. 2, same, but more advanced stage. 3, fruit. 4, scale of strobilus. 5, staminate ament. 6 & 7, lateral buds and leaf scars. (After Illick.)

birches especially can be peeled off like a sheet of paper. The color varies from very dark brown through red-brown and yellow to almost snow white. The young shoots are slender, elastic, and tough, so much so that the quality of the birch rod of the schoolroom has become traditional. Terminal leaf buds are not formed at the close of the growing season (except in *Alnus*), and the shoot continues its growth the next year through the activity of a lateral bud near the tip.

Leaves.—The leaves are simple, serrate, and petiolate, with an alternate arrangement on the stem. In the unfolding bud they have stipules, but these fall off as the leaves expand.

Inflorescences and Flowers.—The flowers are unisexual and usually monoecious. Both kinds are borne in aments that are well begun the season before flowering and rest over winter unprotected by bud scales. Sometimes two or more grow from the same node.

The staminate aments, when expanded, are $1\frac{1}{2}$ to 4 inches long and pendulous. In the axil of each scale are one to three flowers, three apparently being the typical number which is reduced in some species. There may or may not be a calyx. If present it consists of a four-, five-, or six-toothed shallow cup. Petals are absent. The flowers adhere to the bracts and there may be two or four bracteoles more or less united with each bract at its margins.

The pistillate aments are shorter than the staminate (generally a fraction of an inch), erect when young, but somewhat pendulous at maturity. In *Corylus* they are reduced to a few flowers. Two or three flowers are borne in the axil of each scale. The calyx, if present, adheres to the ovary, making the latter inferior. The pistil is bicarpellate, with one or two styles and two stigmas. One or two ovules are found in each chamber of the ovary. In most species the ovules are immature at the time of pollination and the pollen grains germinate and penetrate the styles where they lie dormant for several weeks, until the ovules are ready for fertilization.

Fruits and Seeds.—In most of the Betulaceae the pistillate aments develop into woody cones, doubtfully homologous with the strobili of the gymnosperms. In these matured inflorescences are found seed-like fruits (nutlets), generally one to each scale. In many species they are winged—either two lateral wings or a circular one.

In the hazelnut (*Corylus*) the fruits are larger, $1\frac{1}{2}$ to $3\frac{1}{4}$ inch in diameter, nearly spherical, wingless, and borne in pairs. Each nut is covered by a husk that grows over it from the base and extends an inch or so beyond the apex in the form of a tube. This husk consists of an involucre made up of two united bractlets. The surface is thickly set with stiff, sharp, protective hairs.

Each fruit contains one seed with relatively large cotyledons and no endosperm. The embryo is straight.

Economic Significance.—Few families of woody dicotyledons are as important in northern and temperate countries as the Betulaceae. The wood of the larger birches is of high quality, hard, heavy, strong, and even grained. It is somewhat similar to that of some of the maples. When seasoned it holds its shape well and is used very extensively for interior finishing, floors, furniture, and various small articles such as Indian clubs and other athletic goods, spools, and baskets. When suitably stained it makes an excellent imitation of mahogany. For fuel birch is hardly surpassed by any wood, and alder has been extensively used in the manufacture of charcoal and of black gunpowder.

The bark of several species has been very widely used in basketry, but the great utility of birch bark is for canoes. These light, responsive crafts have for centuries been the chief means of navigation on the swift streams of northern United States and Canada. Extensively used by the Indians, who made them with remarkable skill, they made possible much of the exploration of the American continent by the early traders and missionaries. Thousands of them are still in use, notwithstanding the competition of the canvas canoes made in imitation of them. The tree generally used in their manufacture is the canoe birch (*Betula papyrifera* Marsh.), the white tough bark of which can be peeled off in large sheets.

The inner bark of the birches is rich in starch and in some species, e.g., sweet or black birch (*Betula lenta* L.), it is very palatable and has been extensively eaten in times of distress. There is no better browse for livestock, deer, etc., than birch twigs, either with or without leaves. Hazelnuts and filberts, both being sold under the latter name, are among the best nuts we have. A good, inexpensive imitation of oil of wintergreen is extracted from the bark.

The birch has been well named "The Lady of the Woods." Few, if any, trees surpass it in grace and beauty. The white

species, especially, are extensively grown on public and private grounds and reach their supreme development in the cut-leaved weeping birch, a horticultural variety of *Betula alba* L.

7. FAGACEAE. Beech Family

Members of the *Fagaceae* are familiar to nearly all who live in the vicinity of deciduous forests. There are 5 genera and about 350 species. They are earliest known from the Cretaceous rocks, and during most of the Cenozoic era they were abundant and cosmopolitan. While the Glacial epoch reduced them considerably they are still numerous throughout the north temperate zone with some extensions into the south temperate.

Familiar Examples.—Familiar examples of the *Fagaceae* are beech (*Fagus grandifolia* Ehr.), oak (*Quercus* spp.), and chestnut (*Castanea* spp.), but not the horse-chestnut (*Aesculus* spp.), which belongs to another family (*Sapindaceae*).

Stems and Roots.—All of the family are either trees or shrubs. In each of the three more important genera trees can be found more than 100 feet high and 6 feet in diameter, and a few old monarchs greatly exceed this size. Where grown thickly in the forest the trees have straight, smooth, branchless trunks for half to three-fourths of their height. Growing solitary in the open they form magnificent spreading tops, the lowest branches being but a few feet from the ground.

The roots are somewhat variable. In the beech the older ones near the great trunks are exposed above the surface of the ground. The oaks are very deep rooted forming almost a tap root in some cases. The chestnuts are intermediate in depth of root system.

Leaves.—The leaves are alternate, simple, petiolate, entire in a few species, but generally toothed or cleft. Where stipules form they are fugacious. In *Castanea* and usually in *Fagus* the leaves are deciduous. In *Castanopsis* and *Lithocarpus* they are evergreen while in *Quercus* both kinds are found in different species.

Inflorescences and Flowers.—All the species are monoecious with unisexual apetalous flowers. In *Fagus* the staminate flowers are in dense umbel-like clusters. In the other genera they are in aments, erect or pendulous, often large and abundant, giving the tree a beautiful appearance when in bloom. The pistillate flowers are solitary or two or three in a cluster.

The staminate flowers are borne in deciduous bracts and consist of a small cluster of stamens in a cup-shaped, four- to seven-



FIG. 15.—*Quercus prinoides* (Fagaceae). 1, branch with staminate aments. 2, staminate flower. 3, pistillate flower. 4, fruiting branch. 5, acorn cup formed from the involucre. 6, fruit (acorn). 7, twig in winter condition. 8, leaf scar and lateral buds. (After Illick.)

toothed calyx. A rudimentary pistil is sometimes found with the stamens. The pistillate flowers are three- to seven-carpellate with as many chambers and styles as carpels. There are one or two ovules in each chamber but only one in each ovary develops. The ovary is enclosed in a perigynous four- to eight-toothed calyx which occasionally includes rudimentary stamens also. A many-sealed involucre surrounds the base of each flower.

Fruits and Seeds.—In most species the fruit matures the first season, but in *Castanopsis*, *Lithocarpus*, and some species of *Quercus* not until the end of the second season. The fruit is a nut, borne singly or in twos or threes, in a dense involucre. In the oaks the involucre forms a rough basal cup. In beech, chestnut, and chinquapin it is a prickly bur entirely covering the fruit and opening by four valves at maturity. In the beech and chinquapin the nuts are angled. In the oak and chestnut they are rounded except that in the latter the compressed surfaces of the adjoining three are somewhat flattened. The seed is without endosperm, starchy, nutritious, and well flavored except in the oaks, where in most species it is bitter.

Economic Significance.—The family Fagaceae is the most important of the woody angiosperms. The great abundance and high quality of the wood are well known. Probably more high-class furniture is made from oak than from all other kinds of lumber combined. It is extensively used for floors and interior work. In the days of wooden vessels it was the mainstay in ship building. Its sturdiness is a tradition the world over. The wood of beech is as heavy and strong as that of most of the oaks, much more even grained, and almost impossible to split. It is very resistant to the action of water and free from objectionable taste, hence its extensive use for household utensils, spoons, plates, tubs, vats, etc. Its use in shipbuilding has been second only to that of oak. Chestnut yields a lighter wood not well suited to building purposes where exposed to the weather, on account of checking and warping, but of great value for fence posts, mine props, telephone and telegraph poles, and railroad ties. The devastation caused by the chestnut blight has been one of the greatest tragedies of the eastern forests.

All members of the family are excellent for fuel and are extensively used for this purpose. The oak and beech are rather slow-growing, but the chestnut grows rapidly, especially the second growth sprouting up from stumps.

Throughout all the history of Europe the beech and oak have played a conspicuous part in the traditions, sentiment, and superstitions of the people. The oak has long been symbolic of protective strength. In all regions where these trees will grow they rank among the first for ornamental planting.

The oaks, especially, show a marked tendency to produce cork in the bark. This development reaches its climax in the cork oak (*Quercus Suber* L.) from which it is removed in great sheets for technical use. The bark of other oaks is extensively used in tanning leather.

The nuts of beech, elinquapin, and chestnut are of the finest quality, and a few species of oak, especially *Quercus Michauxii* Nutt., produce edible acorns. Few species of nuts are produced in such quantities as the chestnut. In crowded forests the yield is low, but where the trees are scattered they bear heavily. This nut is so abundant and so desirable as a food product that in some parts of Europe it is even dried and ground into flour. Certain Asiatic and cultivated varieties are much larger than the American species but inferior in flavor.

Where beechnuts, chestnuts, and acorns are abundant they are a valuable source of feed for swine, as these animals eat the fruit of all species regardless of bitter flavors, and they can find them among fallen leaves where human beings would have little success.

8. ULMACEAE. Elm Family

The family Ulmaceae contains about 13 genera and 130 species represented in nearly all the warmer and temperate regions but not extending far into the north. Their geologic history extends back into the Cretaceous period but they are not nearly so well represented in those rocks as the other families of trees just discussed, and not being adapted to cold climates they were exterminated from vast areas during the Glacial epoch. To a limited extent these areas have been reforested.

As the elms and the hackberries are the only members of importance in the United States this account will be restricted to them.

Familiar Examples.—The elms (*Ulmus* spp.) and the hackberries (*Celtis* spp.) are common throughout most of the United States, and the planer tree or water elm (*Planera aquatica* (Walt.) J. F. Gmel.) is found in the southeastern portion.



FIG. 16.—*Ulmus fulva* (Ulmaceae). 1, branch with staminate and pistillate strobili. 2, staminate flower. 3, leaves. 4, fruits. 5, twigs with flower buds and leaf buds. 6, leaf scar and lateral bud. 7, leaf scar. (After Illick.)

Stems and Roots.—The family is composed entirely of trees and shrubs, our white elm (*Ulmus Americana* L.) being one of the largest of the deciduous trees. As a rule the trunks break up into branches a few feet from the ground and these long graceful branches give a beautiful effect. The hackberries are rounder headed than the elms and not quite so graceful.

Leaves.—The leaves are simple and sharply serrate in the elms and some species of hackberry, with prominent veins. They are short-petioled or sessile, with an alternate arrangement on the stem. The stipules, if produced, are deciduous.

Inflorescences and Flowers.—The flowers are apetalous and borne in small clusters or racemes. They may be either bisexual or unisexual, and polygamous or monoecious, with a calyx of four to six sepals united or distinct. The pistil is bicarpellate, with two stigmas, one or two short styles, and a superior ovary.

Fruits and Seeds.—The fruit in the elms is a samara—a nutlet with a broad marginal wing. In the hackberries it is a very small drupe. There is no endosperm, and the embryo is straight.

Economic Significance. Interest in the Ulmaceae centers in the beauty of the elm trees, and in less measure in that of the hackberries. Many make the mistake of trying to grow elms too far north and are disappointed in the results. A little use is made of the lumber for chairs and other furniture. It is fairly tough but not handsome and it does not resist exposure to the weather. When well seasoned it makes good fuel and is much used for that purpose.

9. LORANTHACEAE. Mistletoe Family

The mistletoe family consists of about 21 genera and 500 species, mostly tropical and subtropical, but a few found in temperate climates. Nearly all are parasitic on trees and shrubs. Only two genera and nine species are found in the United States and the following account is restricted to them.

Familiar Examples.—American mistletoe (*Phoradendron* spp.) and small or lesser mistletoe (*Arceuthobium* spp.) are the best known examples of this family.

Stems and Roots. Our mistletoes are small, perennial, usually shrubby plants that grow as parasites on various trees. In length they vary from 1 to 8 inches. The branching is dichotomous. The root takes the form of a haustorium which penetrates the bark and sap wood of the host and from this source

obtains a part or all of the nourishment required by the plant. *Phoradendron* attacks chiefly angiosperms, such as poplars, willows, oaks, and acacia, while *Arceuthobium* attacks gymnosperms, such as pine, larch, and Douglas fir.

Leaves.—The mistletoes are evergreen, and the larger forms are sometimes so abundant in a tree that they give it a leafy appearance during the winter. The leaves are opposite and entire, without stipules. In *Phoradendron* they are about an inch long and half as broad, with a pale green color. They are there-

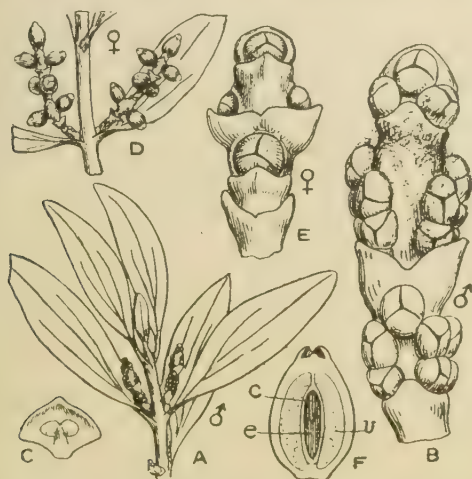


FIG. 17.—*Phoradendron Watti* (Loranthaceae). A, staminate spikes. B, single staminate spike. C, petal with stamen. D, pistillate spikes. E, single pistillate spike. F, longitudinal section of fruit. (After Rendle.)

fore able to contribute something to the nourishment of the plant. In *Arceuthobium* they are reduced to functionless scales, and the plant is strictly parasitic.

Inflorescences and Flowers.—The flowers are solitary or few in the axils of the leaves. They are unisexual and dioecious, regular, and apetalous, with an inferior ovary.

Fruits and Seeds.—The fruit is commonly called a berry, but it is morphologically a tiny one- to three-seeded pome, the fleshy receptacle covering the ovary. This outer covering becomes viscid, enabling it to adhere to the beaks of birds that have attempted to eat the fruits and to the feet of birds and squirrels that happen to have run over them. They are thus carried to other branches where they adhere with sufficient strength to

enable the germinating seed to penetrate the bark. The seeds contain endosperm and the embryo is straight.

Economic Significance.—The Loranthaceae are of no value except as objects of curiosity, and of sentiment in the case of the English mistletoe. They do some damage by distorting their hosts at the point of attachment.

10. POLYGONACEAE. Buckwheat Family

The family Polygonaceae is of medium size, having about 32 genera and 700 species. They are world-wide in distribution, the larger forms showing a preference for the warmer rather than the colder regions.

Familiar Examples.—Buckwheat (*Fagopyrum esculentum* Gaertn.), rhubarb or pieplant (*Rheum Rhaponticum* L.), and various kinds of dock (*Rumex* spp.) are familiar examples.

Stems and Roots.—Considerable variation can be found in the vegetative structure of the Polygonaceae. The majority are herbaceous, but a few in the subtropics and tropics are shrubby and even tree-like. Of the herbaceous members some are annuals, but more are perennials. A few are vines, but many more are erect. As a rule the stems are swollen at the nodes and in some the internodes are hollow. There is a strong tendency to the formation of red pigment in the epidermis.

Leaves.—The leaves are entire or slightly lobed, rarely toothed or cleft. The arrangement on the stem is usually alternate, but sometimes opposite or whorled. The stipules are characteristic of the family with a few exceptions. They are broad and membranous, and form a complete sheath (ocrea) around the stem.

Inflorescences and Flowers.—The inflorescences in the Polygonaceae are quite variable, spikes, racemes, panicles, umbels, and cymes being common. The flowers are apetalous, with a calyx of two to six sepals which are united in some species. The pistil is tricarpellate, or occasionally bicarpellate as in *Oxyria*. It generally has one cavity and one ovule. The ovary is superior, with one to three short styles and usually three stigmas. While the flowers in most species are bisexual, in others they are unisexual and even dioecious. The sepals are often colored and petal-like, white, red, or purple, giving a showy appearance to the inflorescence.

Fruits and Seeds.—The fruit is an achene, which in the usually tricarpellate species is three-angled. It may bear various appendages. In the docks the three inner sepals grow up around it forming three wings. In *Triplaris* the wings come from the three outer sepals. In *Coccolobis* the perianth becomes fleshy. The seed contains a large starchy endosperm and a straight to curved embryo.

Economic Significance.—From a food standpoint the Polygonaceae contain rather important members. Buckwheat is extensively raised in the eastern United States, Europe, and

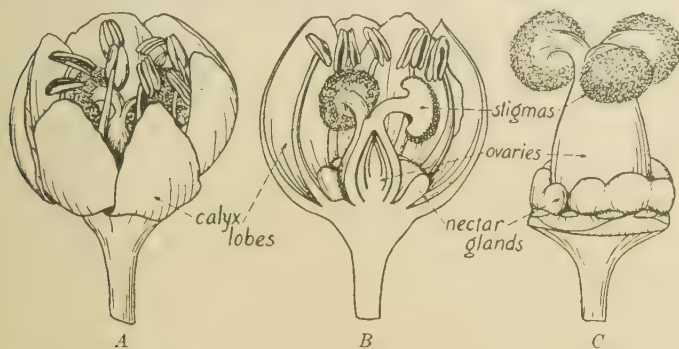


FIG. 18.—*Rheum Rapastrum* (Polygonaceae). A, flower, external view. B, median longitudinal section. C, with perianth and stamens removed. (After Lürssen.)

parts of Asia. It can be grown on very poor soil where few other crops are profitable. The large petioles of rhubarb make a world-wide substitute for fruit in pies, preserves, etc. A considerable number of species, notably buckwheat, secrete abundant nectar which makes honey of fair quality, though rather dark.

A few pernicious weeds belong to this family. Among these are wild buckwheat or bindweed (*Polygonum Convolvulus* L.), sheep sorrel (*Rumex Acetosella* L.), and wild begonia (*Rumex venosus* Pursh). For the most part the plants are unpalatable to stock though not poisonous.

11. CHENOPODIACEAE. Goosefoot Family

The goosefoot family consists of about 75 genera and 500 species of world-wide distribution. A few are semi-xerophytic and many are halophytic, *i.e.*, especially adapted to growth in salty or alkali soil.

Familiar Examples. Among the best known of the Chenopodiaceae are garden and sugar beets (*Beta vulgaris* L.), lamb's quarters (*Chenopodium album* L.), Russian thistle (*Salsola pestifer* A. Nelson), greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.), and summer cypress (*Kochia Scoparia* (L.) Schrad.).

Stems and Roots.—The Chenopodiaceae are mostly annuals, with some biennials and perennials, and a few shrubby species. While they vary considerably in texture, the majority are rather succulent. As a rule they are tap-rooted and under cultivation the roots of some species become fleshy.

Leaves.—The leaves are simple and entire, or variously lobed, and without stipules. As a rule they are glabrous, but in *Chenopodium* especially they are covered with a glandular, mealy pubescence. The arrangement on the stem is alternate, or, in a few species, opposite. In some halophytic forms such as *Sarcobatus*, *Salsola*, *Suaeda*, *Allenrolfea*, and *Salicornia* they are much reduced in size, linear, or even scale-like. In such cases the stems perform largely the function of photosynthesis, and transpiration is slow, to correspond with the slow root absorption from the concentrated soil solution.



FIG. 19.—*Beta vulgaris* (Chenopodiaceae). A, axillary flower cluster. B, same fusing to form "seed ball." (After Robbins.)

Inflorescences and Flowers.—The flowers are usually borne in small axillary clusters or rather dense spikes or panicles at the ends of the branches. They are apetalous and usually bisexual, but not infrequently unisexual and occasionally dioecious. The staminate flowers have a calyx of five or fewer sepals, usually more or less united. One stamen is formed opposite the middle of each sepal, or in some species the number is fewer than the sepals. In the pistillate flower the calyx is similar to that of the staminate flower, but it is lacking in certain genera, e.g., *Atriplex*.

It is free from the ovary or nearly so. The pistil is generally bicarpellate with one seed chamber, one ovule, and one to three styles and stigmas.

Fruits and Seeds.—The fruit proper, *i.e.*, the ripened ovary, is a utricle, a small, dry, one-seeded fruit with a pericarp formed by a persistent calyx, expanded receptacle, or bracteoles, or some combination of these. In the beet these appendages envelop several fruits in one irregular "seed ball." The genera vary as to the presence or absence of endosperm, which, when present, is surrounded by the curved or coiled embryo.

Economic Significance.—The Chenopodiaceae are of considerable importance for food. Because of the succulent nature of the young stems and leaves, and the lack of objectionable flavor, this family surpasses all others for "greens." Spinach (*Spinacia oleracea* L.) and Swiss chard (*Beta vulgaris* var. *Cicla* L.), are the best examples, but garden and sugar beets and even wild forms such as lamb's quarters and Russian thistle are much used and very good. The roots of garden beets as vegetables need no comment.

By far the most important member of the family is the sugar beet. As a source of "cane" sugar, sucrose, it is second only to sugar cane. Sugar beets are not nearly so extensively grown as sugar cane but since they thrive in temperate climates while sugar cane is confined to the tropics and subtropics they make a distinct addition to the total output of sugar.

The Chenopodiaceae have considerable forage value. None of the members are poisonous and a goodly number are abundant, palatable, and nutritious. Even Russian thistles are good forage plants when young, and they have been used for ensilage. The most valuable members on the stock ranges of the west are winter fat (*Eurotia* spp.) and the salt bushes (*Atriplex* spp.). The Chenopodiaceae are the more important because of their ready growth on lands so salty or so alkaline that most other kinds of vegetation cannot occupy them.

A few of this family are troublesome weeds, particularly Russian thistle in the semi-arid parts of the west and lamb's quarters throughout the country. Both these weeds are annuals, intruders on exposed soil only, and quite unable to compete with the grasses when the latter get started.

12. CARYOPHYLLACEAE. Pink Family

In the Caryophyllaceae there are about 70 genera and 1,400 species of world-wide distribution but most numerous in the north temperate zone.

Familiar Examples.—Familiar examples are pinks (*Dianthus* spp.), carnation (*D. Caryophyllus* L.), sweet William (*D. barbatus* L.), baby's breath (*Gypsophila paniculata* L.), and cow cockle (*Saponaria Vaccaria* L.).

Stems and Roots.—The Caryophyllaceae are all herbaceous (a few species slightly woody at the base), annual or perennial, and usually enlarged at the nodes. The annuals are mostly tap rooted.

Leaves.—Almost without exception the leaves are opposite, rarely alternate near the top of the plant. They are entire, usually narrow and sessile, the pair at a node often united to each other around the stem. Stipules are not formed in most species.

Inflorescences and Flowers.—The inflorescence is usually cymose. The typical flower, as found in *Cerastium*, *Agrostemma*, and *Spergula*, for example, is regular, bisexual, and 5-merous, i.e., with five sepals, five petals, ten stamens, and five carpels. By reduction, however, various modifications of this plan have developed. Thus in white campion (*Lychnis alba* Mil.) the flowers are unisexual; in *Loeflingia* there are three to five stamens; in *Scopulophila* there are ten stamens, five of which are functional and five reduced to staminodes; and in *Sagina apetala* Ard. and *Achyronchia Cooperii* T. & G. the petals are absent or reduced to minute scales. Other modifications could be enumerated. This lack of uniformity in the flower need not indicate, however, that the family should be divided, for it is often a variation within the genus or even within the species, as in *Stellaria media* L. where the number of stamens varies from three to ten. As a rule the petals are separate and showy, the sepals are more or less united, and the ovary is superior with one cavity regardless of the number of carpels.

Fruits and Seeds. The fruit is generally a one-chambered dehiscent capsule with seeds varying widely in number. In some species, however, it is a utricle enclosed in a persistent calyx. The embryo is usually wrapped around a central endosperm.

Economic Significance.—The Caryophyllaceae are chiefly valuable for their flowers. These are of many colors, solid or

mixed, often of large size, and easily grown. The plants are unpalatable to livestock. Owing to their vigorous growth and free seeding some members are objectionable as weeds. These are especially chickweed (*Stellaria* spp. and *Cerastium* spp.), corn cockle (*Agrostemma Githago* L.), and cow cockle (*Saponaria Vaccaria* L.).

13. MAGNOLIACEAE. Magnolia Family

Some of the latest phylogenetic systems of classification, notably those of Bessey and of Hutchinson discussed in Chap. VI, rank the order Ranales, or what is sometimes spoken of as the



FIG. 20.—Distribution of Magnoliaceae. The complete isolation of members of this family, considered in conjunction with the anatomical and floral structures, indicates that it is of very great antiquity. (After Hutchinson.)

“ranalean complex,” as the most primitive of the angiosperms. In this basal group the family Magnoliaceae (given the rank of an order by Hutchinson) with its woody structure and large simple flowers stands as the most nearly ancestral form. No one supposes that the first angiosperms were like the magnolias of today; the belief is rather that the trees and shrubs of this family have departed less from the original form than have the members of other families.

This family at the present time is a rather small one consisting of only about 10 genera and 100 species. Their distribution is mostly subtropical and tropical, with a few remaining in the north temperate zone. There is evidence that the family

originated near the arctic circle, perhaps in northern Canada, in the Cretaceous period or earlier, at a time when a subtropical climate obtained there, and that they then spread southward and westward. Extremely abundant throughout most of the Cenozoic era, they might have continued to be a major unit of our forest flora but for the Glacial epoch which they were poorly equipped to resist. They are now recognized as beautiful survivors of a once noble race of trees.

Familiar Examples.—The best examples are the magnolias (*Magnolia* spp.) and the tulip tree (*Liriodendron Tulipifera* L.), which is the "yellow poplar" of lumbermen but is not related to the true poplars (*Populus* spp.) of the Salicaceae.

Stems and Roots.—The Magnoliaceae are all trees or shrubs. As we have in the United States only two genera, those cited as examples above, this description will be limited to them.

The magnolias are best known in the southeastern United States where a half-dozen species are indigenous in moist rich woods and have been freely transplanted to the old plantations and public grounds for the beauty of their flowers and foliage. Most of them are small trees rarely exceeding 60 feet in height, and often taking the form of large shrubs.

Of the tulip trees there are but two remaining species, one confined to the eastern United States and the other, so similar that it is sometimes classed as a variety, found exclusively in China. The tulip tree is of huge size, sometimes 200 feet high and 12 feet in diameter. Even in rather limited shade, the lower branches fall off when very young leaving a smooth straight trunk almost to the top.

Leaves.—Magnolias bear alternate leaves of enormous size, sometimes as much as 30 inches long and a foot wide, generally entire, glossy-green above, thick and leathery. They are deciduous in most species, but evergreen in *M. grandifolia* L. and somewhat so in *M. virginiana* L. Tulip trees have large, thick, lobed or cleft, deciduous leaves. In both genera the leaves are petiolate, with prominent stipules that protect the leaf buds before expanding, and usually ensheath the stem at maturity.

Inflorescences and Flowers.—There is no definite inflorescence, the flowers being solitary but sometimes set rather close together near the tips of the branches. The flowers are the largest and most showy of any of the woody families. In some of the magnolias, *e.g.*, *M. Fraseri* Walt., they are as much as 10 inches

in diameter. In the tulip trees the flowers are cup-shaped and 2 to 3 inches wide, depending on the degree of expansion. The perianth consists of six or nine separate parts, all showy, or the three outer ones green. They are arranged in whorls of three, the outer whorl being the calyx. The flowers are bisexual with many unicarpellate pistils arranged spirally on a cone-shaped receptacle, and many stamens attached to this receptacle below the pistils.



FIG. 21.—*Magnolia Campbellii* (Magnoliaceae). A, vertical section of flower with perianth removed. B, stamen. C seed. D, section of seed. (After Hooker.)

Fruits and Seeds.—Each flower produces many fruits arranged on the receptacle to form a cone several inches long. The individual fruit is a tiny follicle in *Magnolia* and a samara in *Liriodendron*. In *Magnolia* the follicles dehisce and release one or two seeds which remain suspended for a time by slender threads. The very small embryo is embedded in endosperm.

Economic Significance.—The tulip tree is of considerable value for its lumber. It practically never makes solid forests but is found mixed with other deciduous trees. For this reason the supply is limited even within its range. Because of the freedom of the trunks from branches the wood is clear of knots. While it is not heavy or strong or beautiful in grain, there are few species

that surpass it for certain purposes where a light, smooth, easily worked wood is required. Both genera, but especially the magnolias, are of surpassing beauty because of their big waxy-white or yellow tinted flowers, and their great glossy leaves. It is unfortunate that their range is so restricted.

14. RANUNCULACEAE. Crowfoot Family

The family Ranunculaceae contains about 30 genera and 1,200 species of world-wide distribution. They are especially prevalent in temperate climates and some are found in arctic and alpine regions. The affinities of this family with the Magnoliaceae are easily seen and both are classed in the large and somewhat varied order Ranales.

Familiar Examples.—In the crowfoot family, familiar examples are the wind-flower (*Anemone* spp.), peony (*Paeonia* spp.), columbine (*Aquilegia* spp.), larkspur (*Delphinium* spp.), and virgin's bower (*Clematis* spp.). Many of the "buttercups" belong to the genus *Ranunculus* of this family but some are unrelated, belonging to Rosaceae and other families.

Stems and Roots.—The Ranunculaceae are nearly all herbaceous and mostly perennial, but in *Clematis* the stem is somewhat shrubby or takes the form of a woody vine, climbing by petioles that function as tendrils. In some genera, *Actaea*, *Cimicifuga*, and *Thalictrum*, the vascular system is not definitely cylindrical but the bundles are somewhat irregular like those of the monocotyledons. There is a marked tendency for the development of rhizomes and fleshy roots in the perennial species.

Leaves.—Lack of stipules is the only characteristic feature of the leaves in this family, although in nearly all species they have an alternate arrangement. Generally they are large; but in shape they vary from broad and entire, as in *Caltha natans* Pall., to decompose as in *Thalictrum*.

Inflorescences and Flowers.—There is no uniformity as to inflorescence. Many species produce solitary flowers, others irregular clusters. *Delphinium*, *Cimicifuga*, and *Aconitum* develop long racemes and *Thalictrum* has much-branched panicles.

The flowers are likewise variable. Generally they are bisexual, but in some species of *Thalictrum* they are unisexual and dioecious. The sepals are distinct and vary in number from three to fifteen. In most species they are petal-like. The petals vary from three, or rarely none, to fifteen or more. In one branch of the family,

including *Ranunculus* and *Paeonia*, they are alike, forming a symmetrical flower. In the other branch, including *Delphinium* and *Aconitum*, they are irregular, as are also the colored sepals. The stamens are numerous and distinct. The pistils vary in number from one to many and consist of separate carpels which may be slightly adherent, as in *Aquilegia* and *Delphinium*. All parts of the flower are hypogynous.



FIG. 22.—*Delphinium bicolor* Nutt. (Ranunculaceae). This species is representative of the low larkspurs which include also *D. Menziesii* DC., *D. Geyeri* Greene, and *D. Andersonii* Gray. They are found in the plains and foothill regions, from the eastern slope of the Rocky Mountains westward. (One-third natural size.)

Fruits and Seeds.—The prevailing type of fruit is a follicle with many seeds. The different follicles may be adherent at the base to form a loose several-chambered capsule, or they may be distinct. If one-seeded they produce achenes which are often plumed by a development of the style, as in *Clematis* and *Pulsatilla*. In *Actaea* and *Hydrastis* the fruit is a berry. The seed



FIG. 23.—*Delphinium cucullatum* A. Nels. (Ranunculaceae). The tall larkspurs which include also *D. trolliifolium* Gray and *D. Barbeyi* Huth are found in sparsely wooded regions at rather high altitudes in the western mountains. (One-tenth natural size.)

has a copious oily endosperm with a tiny straight embryo embedded near the apex.

Economic Significance.—The Ranunculaceae are best known for their flowers. Many of these, including peony, columbine, larkspur, and clematis, are extensively grown in dooryards. As a family it has a negative value for pasturage, for although wild peony and a few other members contribute a little to the food supply on the stock ranges of the west, this is offset in considerable measure by the losses from eating the poisonous larkspur, *Delphinium*, all species of which are deadly to cattle when eaten in quantity. Sheep and horses seem not to be affected. *Aconitum* is poisonous also, but is not so abundant and is less frequently eaten.

Several important drugs are obtained from this family. The most useful of these are aconite, hydrastis, cimicifuga, and staphisagria.

15. BERBERIDACEAE. Barberry Family

There are about 10 genera and 150 species of the Berberidaceae widely scattered throughout the northern hemisphere and South America, but nowhere of sufficient abundance to form a major part of the flora.

Familiar Examples.—Common or European barberry (*Berberis vulgaris* L.), Japanese barberry (*Berberis Thunbergii* DC.), Oregon grape (*Mahonia* spp.), and wild mandrake or May apple (*Podophyllum peltatum* L.) are familiar examples.

Stems and Roots.—The species found in the United States are all shrubs or perennial herbs. In the woody genera the tissues of wood and bark are yellow.

Leaves.—In *Mahonia* the leaves are evergreen with sharp-toothed margins, and are pinnately compound. In *Berberis* they are unifoliate, only the terminal leaflet developing and the others forming one to five thorns at the base of an apparently simple leaf. In all members of the family the leaves are alternate or basal.

Inflorescences and Flowers.—In *Berberis* and *Mahonia* the flowers are borne in racemes and are generally yellow. In other genera they may be solitary or variously clustered. The flowers are mostly small, bisexual, hypogynous, and regular, with distinct sepals and petals, the same number of stamens as petals, which may vary from four to nine, and one unicarpellate pistil.

Fruits and Seeds.—The fruit of many species is small and fleshy and is generally classed as a berry. In other species it is a small capsule or an achene. The seed has a copious endosperm and a straight embryo.

Economic Significance.—The cultivated barberries introduced from the Orient have been extensively planted in the United States for hedges and ornamental shrubs. Their rapid growth, tough wood, protective thorns, and bright red berries make them almost ideal for this purpose. The common form (*B. vulgaris* L.) is the more vigorous, and a horticultural variety of it has purple foliage. Unfortunately *B. vulgaris* is attacked by the aecial stage of *Puccinia graminis* Pers., the fungus that causes stem rust of wheat, and the perpetuation of this disease in the colder climates is largely dependent on the barberry bush, which is necessary for a completion of the life cycle of the fungus. As hope for control of this wheat rust in the northern United States lies in the extermination of the barberry, a vigorous national campaign is being carried on to that end. The Japanese barberry and all other species of the Berberidaceae found in America are practically resistant to the rust.

16. CRUCIFERAE (BRASSICACEAE). Mustard Family

This important family contains about 200 genera and 2,000 species. They are widely distributed, especially in temperate climates. Most of them are mesophytic although some are semi-xerophytic. Foreign species are finding their way into this country, mostly through impurities in the seeds of crop plants, and many of those now here are becoming more thoroughly distributed as the virgin lands are brought under cultivation.

Familiar Examples.—Of the cultivated species, cabbage (*Brassica oleracea* var. *capitata* L.) and wallflower (*Cheiranthus Cheiri* L.) are well-known, while shepherd's purse (*Capsella Bursa-pastoris* (L.) Medic.) and the various wild mustards (*Brassica* spp., *Sisymbrium* spp., *Courtingia* spp., etc.) are weeds that are common throughout the country.

Stems and Roots.—Nearly all the Cruciferae are herbaceous although a few shrubby species are known. They are usually tap-rooted and in some cultivated species the roots are fleshy. Both annuals and perennials are abundant and a considerable number are biennials.

Leaves.—The leaves are simple, pinnately cleft, or compound, and without stipules. The arrangement is usually alternate but in a few species is opposite.

Inflorescences and Flowers.—In most Cruciferae the inflorescence is a raceme, but cymes are not uncommon. The flowers are small and regular with four petals (rarely none), and four sepals, the inner two usually narrower than the outer. There are six stamens in two whorls; the four inner ones are opposite the petals, and have longer filaments than do the outer ones. The pistil is superior and composed of two carpels with one style and a stigma that is usually two-lobed but in some species is discoid. A false partition extends from one parietal placenta to the other, thus dividing the cavity into two chambers. The flowers are strictly hypogynous with all parts inserted on the receptacle.

Fruits and Seeds.—Two types of fruit are found, long cylindrical siliques and short broad silicles. Some of the latter (*e.g.*, in *Capsella*) have the partition through the short diameter and others (*e.g.*, in *Camelina*) through the long diameter.

The seeds are numerous, rounded, and without endosperm or with very little. The embryo is usually curved.

Economic Significance.—The family Cruciferae contains a few very useful members, contributing especially to the range of garden vegetables adapted to colder climates. Most of these are biennials, their value lying in the food stored the first year of growth. Considerable variation is found in the place of food storage. In turnip (*Brassica Rapa* L.), rutabaga (*B. Napobrassica* Mill.), radish (*Raphanus sativus* L.), and horseradish (*Armoracia rusticana* G. M. & S.) it is in the root. In kohlrabi (*B. caulorapa* Pasq.) it is in the stem. In cabbage (*B. oleracea capitata* L.) and Brussels sprouts (*B. oleracea gemmifera* Zenk.) it is

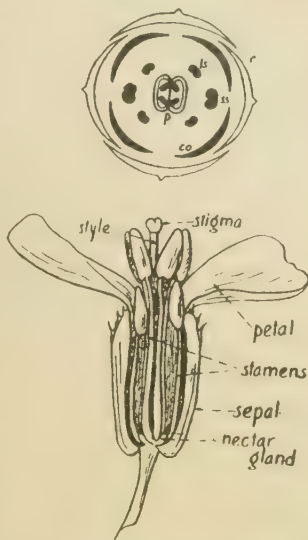


FIG. 24. (Cruciferae). Floral diagram above, longitudinal section of flower below. (After Robbins.)

in the leaves, and in cauliflower and broccoli (*B. oleracea botrytis* L.) it is in the inflorescence. In water-cress (*Radicula Nasturtium-aquaticum* (L.) Brit. & Rend.) there is no localized food storage. Some of the mustards, including wild turnip (*Brassica campestris* L.), field mustard or charlock (*Brassica arvensis* (L.) Ktze.), and black mustard (*Brassica nigra* (L.) Koch) furnish considerable nectar which forms honey of fair quality. It is the more valuable from the fact that it is produced rather early, before the main honey flow in most sections comes on.

Because of the small size of the flowers most species of Cruciferae are not especially ornamental, but a considerable number, wallflower (*Cheiranthus Cheiri* L.), stock (*Mathiola* spp.), candytuft (*Iberis amara* L.), honesty (*Lunaria annua* L.), etc., have been improved to a point where they are handsome.

The table mustard of commerce is obtained from the seeds of black mustard (*Brassica nigra* (L.) Koch) and white mustard (*Brassica alba* (L.) Boiss.).

Owing to the acrid flavor of most members of the Cruciferae they have a limited forage value. The wild crucifers are quite generally rejected, although turnips, rutabagas, cabbage, and rape are grown to a limited extent for stock feed. None of the species of Cruciferae are distinctly poisonous.

Because of their prolific seeding, quick growth, and adaptation to a wide range of environmental conditions, many crucifers have become important weeds. Among the best-known examples are shepherd's purse (*Capsella Bursa-pastoris* L.), field mustard (*Brassica arvensis* (L.) Ktze.), tumbling mustard (*Sisymbrium altissimum* L.), false flax (*Camelina sativa* (L.) Crantz), penny-cress or fanweed (*Thlaspi arvense* L.). For the most part the cruciferous weeds are pests of broken ground. Few of them can make headway in a well-established sod.

17. SAXIFRAGACEAE. Saxifrage Family

The family Saxifragaceae is a somewhat variable one, especially if it be made to include the Grossulariaceae as one of its tribes. Without the currants and gooseberries, as here considered, it contains about 75 genera and 600 species, found chiefly in temperate zones and even extending into the arctic regions.

Familiar Examples. The saxifrages (*Saxifraga* spp.), hydrangea (*Hydrangea* spp.), and syringa or mock orange (*Philadelphus* spp.) are among the best known examples.

Stems and Roots.—The members of this family are mostly perennial herbs or shrubs, but a very few are trees. There is a considerable tendency to vegetative propagation through root-stocks, runners, and bulbils.

Leaves.—The leaves are quite variable. They are mostly spiral, simple, exstipulate, and deciduous, but exceptions are found in all these characters. In the herbaceous forms there is a tendency to produce masses of basal leaves, with slender, leafless stems.

Inflorescences and Flowers.—There is no uniformity or general tendency in the inflorescence. The flowers are mostly bisexual and regular. The typical flower is 5-merous but the carpels are often reduced, two being a common number. They are

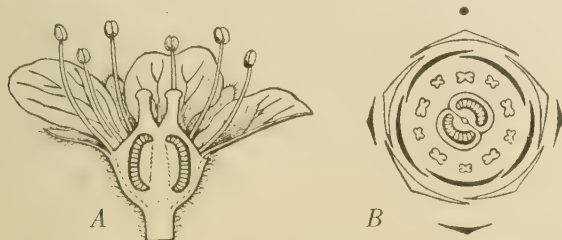


FIG. 25.—*Saxifraga granulata* (Saxifragaceae). A, longitudinal section of flower. (After Warming.) B, floral diagram. (After Eichler.)

separate or loosely united. The stamen number is often twice that of the petals, which are usually five, but are lacking in a few species. The insertion is usually hypogynous or perigynous, but every gradation between may be found.

Fruits and Seeds.—The fruit is generally a capsule or follicle, producing numerous seeds with abundant endosperm and a straight embryo.

Economic Significance.—Except for a few ornamental plants, the family is of little importance. Most of the species are unpalatable to livestock and sparsely produced. It is of considerable botanical interest because of its plasticity and consequent variability.

18. GROSSULARIACEAE. Gooseberry Family

The gooseberries and currants constitute a rather clear-cut family of 1 genus and about 130 species. The family is closely related to the Saxifragaceae and by some authorities is included with them.

Familiar Examples.—Currants and gooseberries (*Ribes* spp.), both wild and cultivated, are the only examples of the family.

Stems and Roots.—The representatives of this family are all shrubs, rather small, mostly from 3 to 8 feet high, in thick clumps. Nearly all species of gooseberries are armed with spines which are extensions or protrusions of the cortex. The few strong spines at the nodes may be supplemented by weaker ones, "prickles," on the internodes.

Leaves.—The leaves are simple, serrate or dentate, and usually with about five lobes. They are alternate and generally long-petioled. Stipules are usually absent or, if present, are reduced to slight margins on the bases of the petioles.

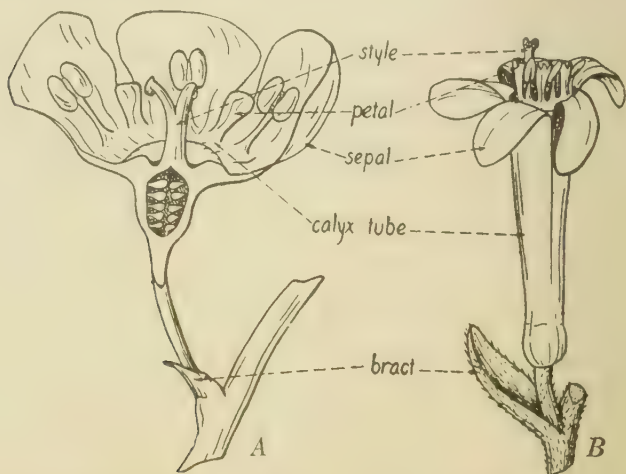


FIG. 26.—A, *Ribes rubrum*. B, *Ribes aureum* (Grossulariaceae). (A, after Sargent; B, after Robbins.)

Inflorescences and Flowers.—The typical inflorescence is an axillary raceme which is usually pendulous and sometimes reduced to three or fewer flowers. The flower is small, regular, and bisexual. It is epigynous, or nearly so, with the receptacle extending to form a "calyx tube" adherent to the ovary. This hypanthium, as it is called, continues in a circular ridge above the attachment to the ovary, and to this the colored sepals, the tiny petals, and the stamens are attached. The sepals, petals, and stamens are five in number, or rarely four. The pistil is inferior and bicarpellate, with two styles, which are sometimes united, and two stigmas.

Fruits and Seeds.—The pistil with its adherent calyx tube grows into a very juicy berry, the wall of which is largely developed from the surrounding receptacle. It contains several seeds and in some species is covered with minute spines. The embryo is small and straight with abundant endosperm.

Economic Significance.—Currants and gooseberries are well known for their richly flavored, strongly acid berries which have become a staple product. Some of the wild species are edible, but others have a disagreeable flavor. Certain species are grown for their profuse yellow or red flowers and graceful form.

19. ROSACEAE. Rose Family

The rose family is rather large, containing about 75 genera and 1,200 species. Its members are of world-wide distribution, only about one-fourth being found in the United States. They have considerable variation in morphological characters, as shown for example in the fruit of the rose and that of the raspberry. It is possible that some of the tribes should be raised to a family rating, but as yet this has not seemed advisable excepting for the Pomaceae and Drupaceae, which are by some considered as separate families and by others as parts of Rosaceae.

Familiar Examples.—Rose (*Rosa* spp.), raspberry (*Rubus* spp.), strawberry (*Fragaria* spp.), spirea (*Spiraea* spp.), and cinquefoil (*Potentilla* spp.) are among the numerous examples of this family.

Stems and Roots.—The Rosaceae are mostly perennial herbs, but some species are shrubs and a few are trees. Many of the shrubby forms are armed with spines which, in *Rosa* and *Rubus*, are protuberances of the cortex from both nodes and internodes. Trailing habit is not uncommon among both the herbaceous and the woody species.

Leaves.—Both simple and compound leaves are common, the latter usually pinnate. With rare exceptions the leaves bear stipules which are generally persistent. The arrangement on the stem is alternate. A few exotic species are evergreen.

Inflorescences and Flowers.—The inflorescence is variable, corymbis rather predominating. The flowers are usually bisexual and tend to be 5-merous, but numerous stamens and unilocular pistils are characteristic of certain genera such as *Geum*, *Potentilla*, *Fragaria*, and *Rubus*. The insertion varies from perigynous in *Rubus* to epigynous in *Rosa*. For the most part the flowers are

large, showy, and symmetrical, but in certain evergreen shrubs of South America they are somewhat irregular.

Fruits and Seeds.—The fruit proper, *i.e.*, the ripened pistil, is typically an achene, a small follicle, or a drupelet. In *Sieversia*, *Geum*, and some other genera the persistent style forms a plume

on the achene. In *Potentilla* it is deciduous and the achene is naked. In *Fragaria* the achenes are partly embedded in the surface of a fleshy pulp formed by a development of the receptacle. In *Rubus* the carpels form as many drupelets attached to an elongated receptacle, thus producing an aggregate fruit. In *Spiraea* the pistils form dehiscent follicles. In *Rosa* the hypanthium surrounds the pistils and becomes fleshy with maturity, embedding the achenes; the whole forming a pome-like fruit, the well-known scarlet "rose hip." The seed has a large straight embryo with no endosperm.

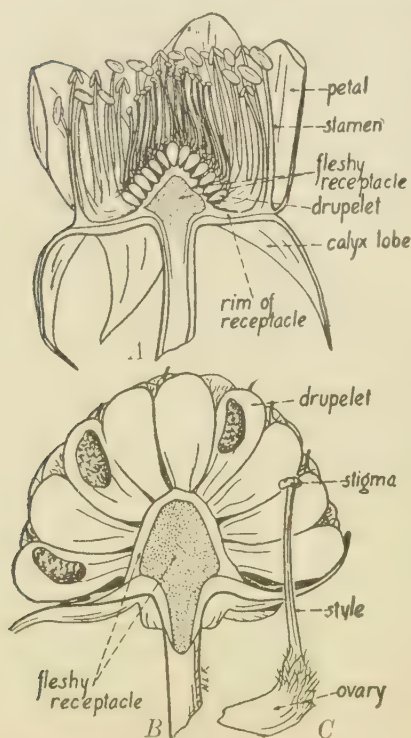


FIG. 27.—*Rubus strigosus* (Rosaceae). A, longitudinal section of flower. B, same of fruit. C, single pistil. (After Robbins.)

Economic Significance.

As a source of fruit this family has only two or three rivals; indeed it may be considered the most

important family for berries. Strawberries, raspberries, loganberries, blackberries, and blackcaps, considered in the aggregate, are of immense value. As food for livestock the family is of limited importance, for while mountain mahogany (*Cercocarpus* spp.), bitterbush (*Purshia tridentata* (Pursh.) DC.), and the wild roses make good browse, most herbaceous species are unpalatable. Many beautiful flowering shrubs belong to this family, especially the roses and the spireas. Probably no other

single genus of plants is as much cherished for its flowers as *Rosa*.

20. POMACEAE (MALACEAE). Apple Family

Formerly a part of the Rosaceae, the Pomaceae are now on good authority given the rank of a distinct family which contains about 20 genera and 500 species of wide geographical distribution.

Familiar Examples.—Well-known examples are apple and pear (*Pyrus* spp.), mountain ash (*Sorbus* spp.), hawthorn (*Crataegus* spp.), and June berry or service berry (*Amelanchier* spp.).

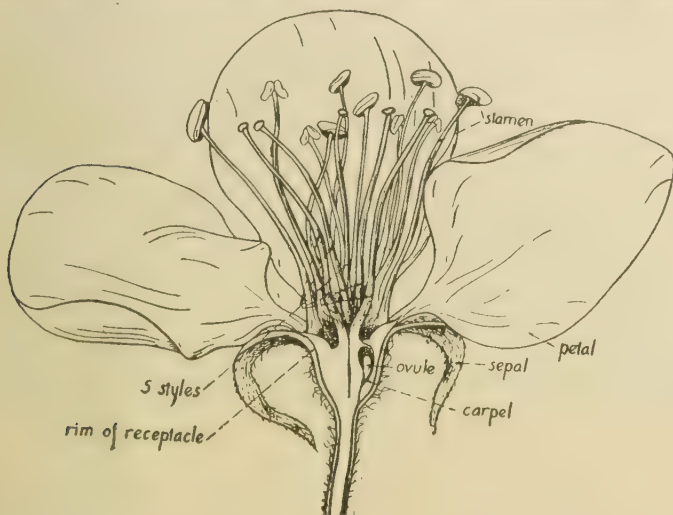


FIG. 28.—*Pyrus malus* (Pomaceae). Longitudinal section of flower. (After Robbins.)

Stems and Roots.—The Pomaceae are all shrubs or trees, some of the older apple trees reaching a diameter of 2 feet or more. The wood of all members is hard and strong. Most species of *Crataegus* are armed with stout thorns that are morphologically lateral branches.

Leaves.—In most genera the leaves are alternate, simple, serrate or dentate, and sometimes slightly lobed. They are provided with petioles and small deciduous stipules. *Sorbus* has large pinnately compound leaves with well-developed stipules that persist until the leaves are fully expanded.

Inflorescences and Flowers.—As a rule the inflorescence is a compound raceme. The flowers are regular, bisexual, and

generally showy. The tendency is to be 5-merous but the stamens are rather numerous, and in some species the carpels are fewer than five—only one in some of the hawthorns. The carpels are firmly united into a single pistil which has an inferior ovary and one to five styles. The insertion is epigynous—sepals, petals, and stamens being attached to a well-developed hypanthium surrounding the ovary.

Fruits and Seeds.—The fruit is a pome which may be very large, as in apple and pear, or small and berry-like, as in mountain ash, service berry, and hawthorn. In most genera the carpels are thin and hard, as in the core of an apple. There is no endosperm, the straight embryo entirely filling the seed.

Economic Significance.—No other family compares with *Pomaceae* in the extent of its fruit production. Literally hundreds of varieties of apples have been developed, with a wide range of colors, sizes, and flavors. They can be grown in different climates and soils, keep longer after picking than most fruits, and are more generally consumed than any other. Pears are important also but their poorer keeping qualities and limited range of flavors rank them far below apples in quantity consumption. Apple wood is used a little for tool handles, and makes excellent fuel when available. The beauty of apple trees in bloom is worthy of mention, and considerable nectar is obtained from the flowers.

21. DRUPACEAE (AMYGDALACEAE). Peach Family

Like the *Pomaceae*, the peach family was set off from the older *Rosaceae*. It contains 3 genera and about 120 species.

Familiar Examples.—The best examples are peach (*Prunus Persica* (L.) Stokes), almond (*P. communis* (L.) Fritsch.), apricot (*P. Armeniaca* L.), plum (*P. spp.*), cultivated cherry (*P. spp.*), and chokecherries (*P. virginiana* L. and *P. melanocarpa* (A. Nels.) Rydb.).

Stems and Roots.—All of the *Drupaceae* are shrubs or trees, some of the wild black cherries growing 100 feet high and 4 feet in diameter. The bark has a bitter taste due to traces of prussic acid and tannin. It also contains a glucoside, amygdalin, from which prussic acid is formed through the action of an enzyme, emulsin. When wounded the bark exudes a gum which is supposed to protect it to some extent.

Leaves.—The leaves are alternate, simple, petiolate, serrate, and provided with small deciduous stipules. Usually a few conspicuous glands are found on the petioles. Like the bark the leaves contain prussic acid and amygdalin.

Inflorescences and Flowers.—The species vary in type of inflorescence. It may be umbellate, corymbose, or racemose, or the flowers may be solitary or in twos or threes. The flower is usually regular and complete, *i.e.*, bearing a full set of floral

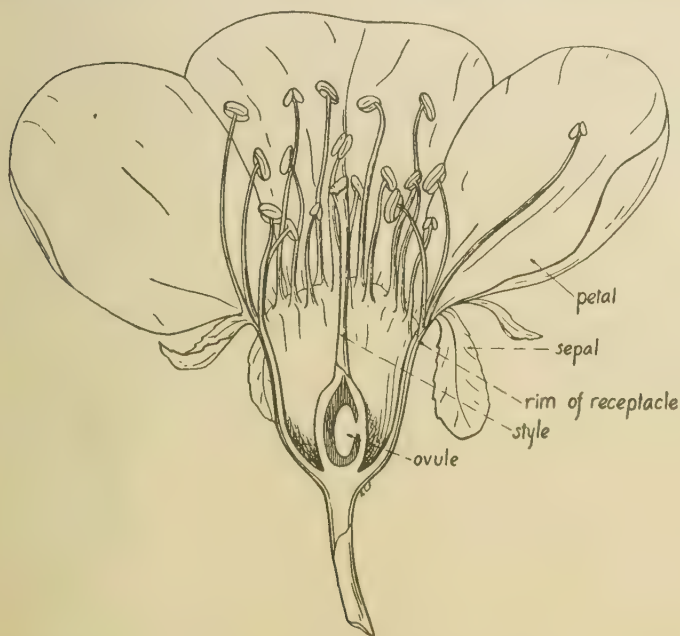


FIG. 29.—*Prunus cerasus* (Drupaceae). Longitudinal section of flower. (After Robbins.)

organs. The insertion is perigynous, leaving the unicarpellate pistil free. The petal and sepal number is five and the stamen number is typically ten, fifteen, or twenty.

Fruits and Seeds.—The fruit is a drupe which is velvety in the peach and almond, but glabrous in most of the other species. The ovary wall develops into three layers, an outer epicarp or skin, a middle mesocarp or pulp, and an inner endocarp or stone. In the almond the mesocarp is leathery in texture. Although the pistil contains two ovules, usually only one forms a seed; the

other fails to develop. In the almond two seeds are not uncommon. They contain prussic acid and amygdalin in amounts varying with the species—strong in bitter almond and apricot, but very little in the ordinary sweet almond. The seed is large but without endosperm. The seed coat is very thin, its function of protection being usurped by the endocarp of the fruit.

Economic Significance.—The Drupaceae rank second or third among the families in fruit production. Were peaches, cherries, and other stone fruits as good keepers after ripening as apples and oranges, they would probably be raised in greater abundance than either. Under the circumstances, the limiting factor in their production is the amount that can be consumed and preserved within a few weeks each season. Almonds are commonly classed as nuts although morphologically they are quite different. They are in such demand that the few regions of this country where the climate is suitable for their production are used to capacity.

In the eastern half of the United States where cherry grows wild and produces large trees, these are valuable for lumber. Cherry wood is reddish in color, rather heavy, moderately strong, and close grained. It is excellent for furniture and interior finishing, and can be stained to imitate mahogany.

Some of the members are valuable for their prussic acid content. This may, however, be a source of danger, for children have been poisoned by eating the seeds of peaches and apricots, and when feed is scarce livestock will browse the leaves and twigs of wild cherry, a fact which has sometimes resulted in serious losses.

22. PAPILIONACEAE (FABACEAE). Pea Family

The name Leguminosae has long been applied to a large and important group of plants. The members are doubtless related, as shown by certain flower, fruit, and leaf characters, but they fall rather naturally into three or four groups that may be considered tribes, subfamilies, or distinct families. If they are regarded as families the Leguminosae may be given the rank of an order, as is done by Hutchinson. The largest and most important of the families of the Leguminosae is the Papilionaceae, which contains most of the herbaceous forms and some shrubs and trees. The entire group Leguminosae contains about 550 genera and 12,000 species, of which some two-thirds belong to the

Papilionaceae. It is therefore the second largest family of the dicotyledons. It nearly equals the Orchidaceae in species number, and is more numerous in individual plants and distributed much more abundantly northward.

Fossil remains indicate that some woody members of the Leguminosae, including a few of the Papilionaceae, were in existence during the latter part, at least, of the Cretaceous period, but most of the species, perhaps all the herbaceous ones, are products of the latter part of the Cenozoic era. Their present distribution is cosmopolitan.

Familiar Examples.—Familiar examples are clovers (*Trifolium* spp.), alfalfa (*Medicago sativa* L.), sweet pea (*Lathyrus odoratus* L.), garden pea (*Pisum sativum* L.), bean (*Phaseolus* spp.), lupine (*Lupinus* spp.), and black locust (*Robinia Pseudo-Acacia* L.).

Stems and Roots.—The Papilionaceae are predominantly herbaceous, but a few are shrubs, woody vines, or trees. The largest member of the family is the black locust, which not infrequently reaches a height of 80 feet and a diameter of 2 to 3 feet.

The root system in the perennial species is generally large and deep, as in alfalfa, for example. The roots of most species are commonly attacked by bacteria belonging to the genus *Rhizobium*. These enter through the root hairs and cause what appears to be a diseased condition, in that certain cells are killed and inhabited by the bacteria, and other cells are stimulated to abnormal multiplication which results in the formation of many tiny galls or nodules. This localized injury is more than offset, however, by the benefit the host receives from the bacteria, which are among the few species that have the power of using the inert nitrogen of the air and uniting it with other elements to form compounds usable for food by the leguminous host.

Leaves.—With few exceptions the leaves are compound, more often pinnate than palmate, and possessed of permanent stipules. The arrangement on the stem is alternate. In several genera, such as *Lathyrus*, *Pisum*, and *Vicia*, the terminal leaflet, and sometimes others, is reduced to a tendril. Movements of the leaflets or the leaves are fairly common. In *Trifolium* and *Phaseolus*, for example, the leaflets take a vertical position as darkness comes on. In the sensitive plants, *Mimosa pudica* L. and *Aeschynomene virginica* (L.) B.S.P., the petiole droops and the leaflets fold together when the latter are touched. In

Desmodium gyrans DC., the telegraph plant, two lateral leaflets wave up and down periodically without external stimulus.

Inflorescences and Flowers.—The most common inflorescence in the Papilionaceae is a raceme, which in some cases, as the clovers, is shortened to such an extent that it is often spoken of as a head.

The flower is quite characteristic in most species. Generally it is complete and hypogynous or perigynous. The five or four sepals are more or less united. The five petals are unlike, forming an irregular flower with bilateral symmetry. The large upper petal is called the standard. On either side are two others, similar to each other, called the wings. Below these, and more

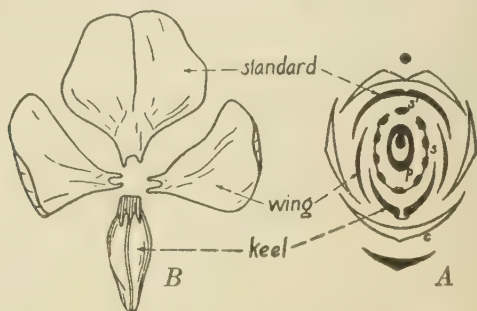


FIG. 30.—A, *Vicia faba*. B, *Lathyrus odoratus* (Papilionaceae). (A, after Eichler, B, after Bergen and Caldwell.)

or less enclosed by them, is the keel, which consists of two united petals, the others being distinct. In *Amorpha* the wings and keel are wanting, and in several species of *Lespedeza* some of the flowers are apetalous. There are generally ten stamens, which in most species have their filaments united into one or two series. The pistil contains a single carpel with a superior ovary. A considerable number of species show highly specialized devices for insect pollination. In this respect the family almost approaches the Orchidaceae.

Fruits and Seeds.—Each flower develops a single true pod, often called a legume. Commonly the pod is dehiscent, but not infrequently it develops into a special indehiscent hooked structure for seed distribution by animals. In *Glycyrrhiza* the pod is short and unsegmented and bears well-developed hooks. In *Desmodium*, *Hedysarum*, and other genera of the same tribe the pods are divided transversely into easily separated segments covered with very fine hooks, and contributing to that hetero-

geneous group of fruits known as "beggars lice." In *Medicago* the pods are small, spirally coiled, and either hooked or reticulated. The peanut (*Arachis hypogaea* L.) fruits in a very special way. As soon as the flowers in the axils of the lower leaves are fertilized they lose their petals and the peduncle turns downward, forcing the ovary into the soft soil. When thus buried it develops into the well-known peanut. If it fails to get buried because it started too far above ground or the ground was too hard, the ovary withers and dies. The seeds of Papilionaceae contain a large curved embryo, with little or no endosperm.

Economic Significance.—The Papilionaceae rank second only to Gramineae in value to mankind. Probably a wider range of usefulness is found here than in any other family. Much significance lies in the fact that the Papilionaceae are highly nitrogenous in all their tissues. For this reason they supplement well the foods and feeds obtained from the Gramineae, which are largely of a carbohydrate nature. The special food value of peas and beans is well known, and the fine flavor and oil and protein content of peanuts make them usable in many forms. No other plant except timothy yields so much hay as clover and alfalfa, and the pasture value of the legumes ranks above all others except the grasses.

Even if the legumes were wholly unpalatable they would be extensively raised, however, because of their value to the soil. For centuries it has been known that crops of this character enrich the soil although other crops impoverish it. The explanation has been given on page 169. The decaying roots and stubble bring much available nitrogen into the soil even though the stems and leaves are removed for hay. It is indeed rare good fortune that after the harvesting of an unusually valuable crop, such as clover or alfalfa, the land is left in much better condition for other crops. Man's benefit by the alliance between leguminous plants and the bacteria that inhabit their roots is incalculable.

As a source of honey no other family compares with the Papilionaceae—indeed in many states the yield from this family exceeds that from all other families combined. In white and alsike clovers, alfalfa, and sweet clover we have four of the greatest honey producers, and the quality is of the best.

In esthetic value this family ranks high. It includes myriads of beautiful wild flowers, and sweet peas and black locust illustrate the cultivated forms.

From no other family are so many official drugs obtained. These include licorice, hematoxylin, tragacanth, senna, and physostigma.

Two important groups of stock poisoning plants are found in this family, namely the locoes and the lupines. The locoes



FIG. 31.—*Oxytropis Lamberti* Pursh (Papilionaceae). White or stemless loco. This plant is found in the open country from the Rocky Mountains eastward to Minnesota. (One-half natural size.)

include *Oxytropis Lamberti* Pursh and a few species of *Astragalus*, notably *A. mollissimus* Torr. The poisonous principle in these plants is unknown, and its effects are evident only after continuous feeding for weeks or months. Loco poisoning causes

heavy losses in horses, cattle, sheep, and goats. The lupines cause acute poisoning, especially in sheep. The poisonous principle has not been isolated, but the losses are mostly from eating young pods containing seeds. The mature pods are so freely dehiscent that ripe seeds rarely are eaten in quantity.

For so large a family, the Papilionaceae are remarkably free from members that are classed as noxious weeds. This is in part because some that have the persistent habit of weeds are so freely eaten by livestock that they are thought of as forage plants



FIG. 32.—*Lupinus sericeus* Pursh (Papilionaceae). The lupines, of which there are many species, are found at nearly all altitudes throughout the western half of the United States. (One-fourth natural size.)

rather than weeds. In many places white, alsike, and sweet clovers abound, but although "plants out of place" they are not classified as weeds. A few, such as wild licorice or buffalo bur (*Glycyrrhiza lepidota* Pursh), are obnoxious.

23. GERANIACEAE. Geranium Family

There are in the Geraniaceae only about 11 genera and 650 species, found mostly in temperate climates and especially prevalent in South Africa.

Familiar Examples.—Wild geranium or cranesbill (*Geranium* spp.), cultivated geraniums (*Pelargonium* spp.), and storksbill (*Erodium* spp.) are the only members of the geranium family commonly found in this country.

Stems and Roots.—The plants are all herbaceous excepting a few exotic half-shrubs. Our species are mostly perennial. Fleshy roots and rootstocks are common.

Leaves.—The leaves are generally deeply cleft or even compound. They are alternate or opposite, petiolate, usually stipulate, and in most species thickly covered with glandular hairs.



FIG. 33.—*Geranium dissectum* (Geraniaceae). a, floral branchlet. b, flower. c, dehiscent fruit. d, seed. (After Jepson.)

Inflorescences and Flowers.—Cymes are the commonest form of inflorescence, but umbels are found in *Pelargonium*. The flowers are showy, generally regular, but slightly irregular in *Pelargonium* and *Erodium*, bisexual, and 5-merous. Each flower is borne in a pair of small bracts. The sepals are distinct or united at the base. The petals are separate and hypogynous. There are usually five, ten, or fifteen stamens, some of which may be abortive, or, as in *Erodium*, reduced to staminodes. The pistil is

usually 5-carpellate with one style and a superior ovary. The general effect of the flower, and indeed of the entire plant, is suggestive of the Rosaceae, but in Rosaceae the stamens are usually more numerous and the carpels numerous and distinct.

Fruits and Seeds.—The fruit is characteristically a beaked capsule with a persistent calyx on a long reflexed peduncle suggestive of the head and neck of a bird—hence the name cranesbill. In most species the capsule dehisces from the base upward. Each chamber contains but one seed, the other ovule having aborted. In *Erodium* a portion of the style remains attached to

the seed as a hygroscopic awn. The seed contains little or no endosperm and an embryo that is usually curved.

Economic Significance.—Most of the Geraniaceae are palatable to livestock and make good forage. The flowers are handsome and abundant. Probably the common greenhouse geranium is grown in more homes than any other flower.

24. LINACEAE. Flax Family

The family Linaceae is a rather small one, containing only 9 genera and about 150 species.

Familiar Examples.—The best examples are cultivated flax (*Linum usitatissimum* L.), wild perennial flax or Lewis' flax (*L. Lewisii* Pursh), and yellow flax (*Linum* spp.).

Stems and Roots.—The species found in the United States are all herbaceous, although a few foreign species are shrubby. The plants are tap rooted.

Leaves.—For the most part the leaves in Linaceae are entire, narrow, sessile, and alternate. Stipules are absent or fugacious.

Inflorescences and Flowers.—The flowers are axillary or terminal on the upper branches, which may be so close as to give a corymbose or cymose effect. They are showy, bisexual, regular, hypogynous, and mostly 5-merous. The sepals and petals are distinct. There are usually ten stamens in two whorls, the outer whorl being reduced to staminodes and the inner one united at the base. The pistil is composed of two to five united carpels, each of which has its cavity divided by a false partition giving the effect of four to ten carpels. Each apparent chamber encloses one ovule. The ovary is superior and the style number varies from one to five.

Fruits and Seeds.—The fruit is a capsule, which in flax is apparently ten chambered. It normally contains ten seeds and is slightly dehiscent along the lines of the true and false partitions. The seed contains a straight embryo and little or no endosperm.

Economic Significance.—The importance of Linaceae centers in one species, common flax, of which there are a number of varieties. This crop supplies us with linseed oil, for which there is no satisfactory substitute obtainable in sufficient quantity for the manufacture of house paint. It is extracted from the seed, and the "oil cake," remaining after it has been expressed, is of value for stock feed. Our linen cloth is made from fiber removed from the bast of the bark by a process of "retting." It is wholly

superior to all other fibers for certain purposes. Unfortunately flax to be used for seed and that to be used for fiber must be grown and harvested under different conditions. In America most of the flax is raised for seed and the straw is discarded or fed to stock in times of famine. Most of our fine linen is produced in Europe.

The flowers of flax are beautiful when growing, but the petals fall quickly when they are picked.

25. RUTACEAE. Rue Family

The Rutaceae are little known in the United States, except through their cultivated forms, the citrus fruits. There are, all told, about 120 genera and 900 species, mostly tropical and subtropical, and especially prevalent in Africa and Australia. In this country we have but three native genera with one or two species each.

Familiar Examples.—Familiar examples of the rue family are orange, lemon, and grapefruit (*Citrus* spp.), prickly ash (*Zanthoxylum* spp.), and hop tree (*Ptelea trifoliata* L.).

Stems and Roots.—The Rutaceae are nearly all shrubs or small trees. In some species, such as lemon and prickly ash, the stems are protected by short, stout thorns. The bark is often fragrant.

Leaves.—The leaves show much variation. They are simple, or more often pinnately compound, and in the latter case some are apparently simple by reduction of leaflets to one. The arrangement on the stem is alternate, or less frequently opposite, and a considerable number of species, including the citrus fruits, are evergreen. In many species there is an extensive production of aromatic glands in the leaves.

Inflorescences and Flowers.—The flowers are usually borne in cymes. They are typically 5-merous but multiples of three and four are common. They are regular or slightly irregular, and are hypogynous, with a circular disc inside the whorl of stamens and bearing the pistil. The two to five carpels may be closely or loosely united.

Fruits and Seeds.—The fruit may be a samara, a capsule, or a berry; in the latter case it grows to great size in some of the citrus fruits. Each carpel produces from one to many seeds which may or may not contain endosperm, the embryo being straight or curved. In some species of *Citrus* more than one

embryo develops in a seed, sometimes as many as thirteen, of which two or three may germinate.

Economic Significance.—Climatic conditions limit the growth of the Rutaceae in this country. The native species are interesting aromatic shrubs and trees of little value. The introduced citrus trees, however, are grown successfully in the Gulf States and California both for fruit and for ornament. So intensively are they grown in the limited areas that are suited to them that the family takes third place in fruit production. The good keeping and shipping qualities of oranges, lemons, and grapefruit, combined with their fine flavor and wholesomeness, insure their continued prominence in the markets.

A few important drugs are extracted from the leaves and the rinds of the fruits, notably oil of citron, oil of bergamot, and oil of lemon.

26. EUPHORBIACEAE. Spurge Family

The family Euphorbiaceae is a large and extremely variable one, containing about 220 genera and 4,000 species. They are of wide geographic distribution, but are most abundant in the warmer climates, with few species extending beyond the Canadian border.

Familiar Examples.—Familiar examples of the spurge family are castor bean (*Ricinus communis* L.), crown-of-thorns (*Euphorbia splendens* Bojer.), snow-on-the-mountain (*Euphorbia marginata* Pursh), and poinsettia (*Euphorbia heterophylla* L.).

Stems and Roots.—Most of the family are herbaceous, but shrubs and trees are not uncommon in the tropics. The juice is acrid and in many species milky from the presence of starch, gums, and resins.

Leaves.—The leaves are mostly simple, with an alternate, opposite, or whorled arrangement, and in some species they have been reduced to spines.

Inflorescences and Flowers.—As would be expected in so large a family, there is considerable variety of inflorescence, but cymes are rather predominant. So great a variation is shown in the flowers that only general tendencies will here be indicated. Scarcely a statement can be made but will require exceptions. For the most part the flowers are 3-merous. Perhaps the most nearly constant character is the tricarpellate pistil. The tendency to reduction and specialization is very marked. This

reaches its climax in *Chamaesyce* where the flowers have neither petals nor sepals and are unisexual, the staminate flower consisting of a receptacle and one stamen, and the pistillate flower a peduncle, a receptacle, and a pistil. In some species the leaves just under the flowers are white or red, giving the plant a striking appearance.

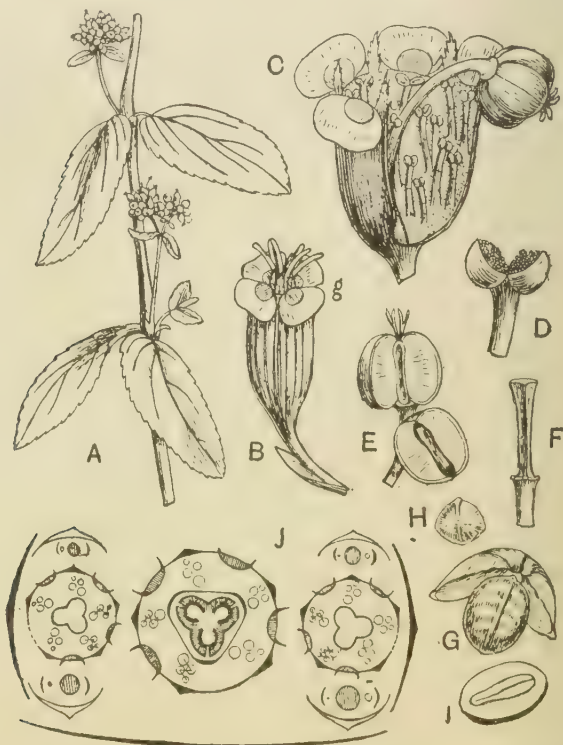


FIG. 34.—*Euphorbia hypericifolia* (Euphorbiaceae). A, inflorescences in clusters. B and C, single inflorescence (cyathium). D, stamen. E, fruit. F, axis of fruit. G, portion of fruit. H, seed (external). I, seed (internal). J, diagram of inflorescences and flowers of *E. peplis*. (After Rendle.)

Fruits and Seeds.—The characteristic fruit is a three-chambered capsule, each chamber containing one seed, or the carpels may separate into three nutlets. The seed has a straight embryo and contains endosperm which is usually oily.

Economic Significance.—The Euphorbiaceae contribute but little to the food supply, although tapioca and other products of the fleshy root of *Manihot utilissima* Pohl. are worthy of mention.

In general the herbage is unpalatable to livestock. Notwithstanding its deficiency in edible plants this family is one of the most important to mankind because of the commercial and medicinal products extracted from the milky juice, the seeds, and the tissues of its numerous members. First in rank is caoutchouc, which, being manufactured into rubber, needs no introduction to any reader. It comes from the milky juice of several species of *Hevea*, *Mabea*, *Mamhot*, and *Sapium*. Wood oil, artist's oil, and other drying oils, some of which are even better for paint than linseed oil, are extracted from the seeds of several species. Powerful drugs, especially those of a cathartic or irritant nature, are produced by many members. Probably no other plants have been used in the crude state for medicine so much as the Euphorbiaceae. Their properties have been discovered by natives the world over. In this country we now use castor oil, croton oil, cascarilla, hurta, and other products. A considerable number of deadly poisons are produced by exotic members of this family. Of these some are especially injurious through the stomach, others through wounds or when applied to the skin, and others are blinding to the eyes. It is not surprising, therefore, that they should have been used so much for warfare, murder, and suicide, and to kill fish, game, and insects.

Because of the brilliant color of the leaves surrounding the flowers a few species are used for ornamental purposes. The best known of these is the greenhouse poinsettia. The crown-of-thorns, with its weird, bare, spiny stems and gay floral bracts, is frequently grown as a house plant, and the castor bean is found in thousands of dooryards and flower gardens.

27. ACERACEAE. Maple Family

The maple family is a small one, containing only 2 genera and about 120 species. They are mostly confined to the north temperate zone and are especially prevalent in the eastern half of the United States. Like so many of our trees, their ancestry can be traced back to the Cretaceous period. Their place of origin appears to have been northern Canada or Greenland. The Glacial epoch greatly reduced the area covered by the maples and nearly exterminated them from northern and central Europe, but most species survived in favored localities. As a result we often find the same species in restricted spots on both continents of the northern hemisphere, with thousands of miles intervening.



FIG. 35.—*Acer saccharum* (Aceraceae). 1, staminate inflorescences. 2 and 3, staminate flower. 4, pistillate inflorescence. 5, pistillate flower. 6, bisexual flower. 7, fruits. 8, longitudinal section of fruits. 9, twig with leaf scars and buds. (After Illick.)

Occasionally they make nearly solid forests, but more often they are mixed with trees of other families.

Familiar Examples.—The maples (*Acer* spp.) and the box elder (*A. Negundo* L.) are examples of this family.

Stems and Roots.—Nearly all members of the family are trees, some of them more than 100 feet high and 3 to 4 feet in diameter. A few species are shrubs. In forests the trunks of most species are straight, with the lower half free from branches. Standing alone, the trees branch widely and are nearly as broad as high. They are rather slow in growing but long lived. The buds are prominent and protected by large scales.

Leaves.—The leaves are broad, variously cleft, or, in the box elder, pinnately compound. They are petiolate, exstipulate, and opposite.

Inflorescences and Flowers.—The flowers are borne in small axillary clusters, which take the form of racemes or cymes. They may be either bisexual or unisexual. Most maples are polygamous, the same inflorescence bearing both bisexual and unisexual flowers. The box elder is dioecious. In bisexual flowers there are generally five distinct sepals, five small, distinct, regular petals, eight stamens, and one bicarpellate pistil with two styles and a superior ovary.

Fruits and Seeds.—The fruit is a characteristic samara with one wing, each flower producing a pair, loosely attached to each other at the base, with wings diverging. These are the well-known "keys." The embryo is curved or crumpled, and there is usually no endosperm.

Economic Significance.—The maples are among our most valuable forest trees. The lumber is cut to the extent of a billion board feet annually in the United States. It is exceedingly hard, strong, and close grained, and some varieties or individuals develop the beautiful "bird's eye" grain so much prized for furniture and musical instruments. With the exception of oak no other wood is used so much for implements and hardwood floors. For fuel it is famous, and the maple back-log for the fireplace has become celebrated throughout the east. The fertilizer value of the leaves and the ashes has long been recognized. For ornamental planting the maple trees will hold their own with the best. Nor must we forget the delicious maple sugar and syrup obtained from the sap of *Acer saccharum* Marsh. The maple family is one having many good traits and no bad ones.

28. VITACEAE. Grape Family

The grape family contains only about 10 genera and 500 species. They are widely distributed in temperate and subtropical regions.

Familiar Examples.—Grape (*Vitis* spp.), Virginia creeper (*Parthenocissus quinquefolia* (L.) Planch.), and Boston ivy (*P. tricuspidata* Planch.) are well-known examples of this family.

Stems and Roots.—The Vitaceae are mostly vines, climbing by tendrils or by adventitious roots. The tendrils have a special

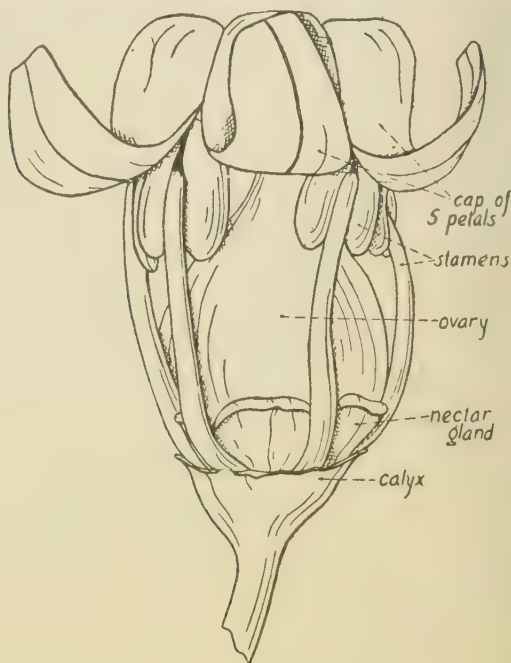


FIG. 36.—*Vitis* (Vitaceae). Partly opened flower. (After Robbins.)

morphological interest. They are borne at the nodes, opposite the leaves, and it is held on good authority that each represents the tip of the main shoot which has been pushed aside by the growth of a lateral bud at its base. In some species the tendrils develop adhesive discs at their tips. A few tropical species are shrubs or small trees. The nodes are enlarged and the vines and tendrils are tough and strong. The grape, especially, contains an abundance of watery juice.

Leaves.—The leaves may be simple as in the grape, or they may be compound as in the Virginia creeper. They

are petiolate with deciduous stipules and an alternate arrangement.

Inflorescences and Flowers.—The flowers are usually borne in panicles or cymes, which take the place of tendrils opposite the leaves at certain nodes. They are small and either bisexual or unisexual, in some species dioecious. The calyx is four or five toothed or reduced to an inconspicuous ring. The petals are of the same number, greenish in color, and generally fall as soon as the flower opens. There are four to five stamens, always opposite the petals, and a bicarpellate pistil, which is more or less embedded in a circular disc.

Fruits and Seeds.—The fruit is a berry, well illustrated by the grape. The seed contains oily endosperm and a small embryo.

Economic Significance.—Grapes are extensively raised the world over in all but the colder climates. Their use for food and for wine goes back to the dawn of civilization, and much attention has been given to the development of varieties especially suited to the different uses. Vast quantities are dried into raisins, and the so-called dried currants are in reality made from certain varieties of tiny grapes.

The Vitaceae furnish the best of our climbing woody vines, some species having the very desirable feature of climbing over brick or stone buildings by their disc-like tendrils and aerial roots, thus eliminating the need of trellises. They are made more attractive by their brilliant autumn colorings.

29. MALVACEAE. Mallow Family

The mallow family, sometimes known as the cotton family, contains about 50 genera and 1,000 species, many of which are confined to the tropics and subtropics. The family is represented in all parts of the world excepting the arctic zones.

Familiar Examples.—Cotton (*Gossypium* spp.), hollyhock (*Althaea rosea* Cav.), and hibiscus or rose mallow (*Hibiscus* spp.) are examples of the Malvaceae.

Stems and Roots.—The members of this family are mostly herbaceous, but in the tropics some shrubs and small trees are found. Usually they are sturdy erect plants, but a few, as *Malva rotundifolia* L. and *Sida hederacea* Torr., are decumbent.

Leaves.—The leaves are generally large, broad, simple, and palmately veined, with petioles and deciduous stipules. They are alternately arranged on the stem.

Inflorescences and Flowers.—The flowers are either terminal or axillary, or sometimes in loose racemes. For the most part they are regular in shape, large, and showy. In many species each flower is subtended by three or more involueral bracts. With few exceptions the flowers are bisexual and hypogynous with a tendency to be 5-merous except for the large number of stamens. These are monadelphous, with their filaments united to

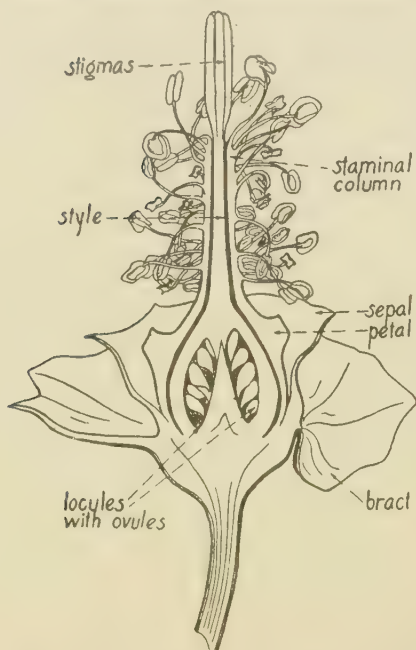


FIG. 37.—*Gossypium hirsutum* (Malvaceae.) Longitudinal section of flower. (After Robbins.)

form a conspicuous column encircling the pistil. Each pistil contains several carpels, five being the commonest number, but in different species they vary from one to many.

Fruits and Seeds.—The fruit is usually a capsule with each cavity containing one to several seeds. The seed has more or less endosperm and a straight or curved embryo. The seed coat is generally naked, but in a few species, notably in the genus *Gossypium*, it is densely tomentose. The hairs on the seeds furnish the cotton fiber of commerce. Each fiber or hair is the extension of an epidermal cell of the seed coat.

Economic Significance.—The cotton plant is the world's greatest source of textile fiber. Probably cotton is used for clothing and bedding more than are wool, silk, and linen combined. It is abundantly produced in most of the warmer countries, is relatively inexpensive, and is of better quality than any other commercial plant fiber excepting linen.

Much use is made of the oil from the seed as a substitute for lard, and of the remaining "oil cake" for stock feed. A few of the wild hollyhocks and mallows make good pasturage but they are not sufficiently abundant to give the family much forage value.

The large size and variety of color found in the flowers of the hollyhock and many other species give them a prominent place in dooryards and flower gardens.

30. VIOLACEAE. Violet Family

The Violaceae include about 18 genera and 450 species which are widely distributed.

Familiar Examples.—Violets (*Viola* spp.) and pansies (*V. tricolor* L.) are familiar examples.

Stems and Roots.—The representatives found in this country are all herbaceous and mostly perennial, but a few tropical forms are shrubby.

Leaves.—The leaves are simple and variously toothed, with a marked tendency to be cordate in form. They are petiolate with usually permanent stipules. In many species they are all basal, but in others alternately arranged.

Inflorescences and Flowers.—As a rule the flowers are solitary on long peduncles, but a few are racemose. In several of the genera the flowers are regular, but in *Viola*, the largest and best-known genus, they are irregular with a spur on the basal petal. They are 5-merous excepting the pistil, which is tricarpellate. The parts outside the pistil are free or slightly connate. In some of the violets two kinds of flowers are produced. Those that appear first are showy, as just described. They often fail to produce seed. These are followed by apetalous ones which are self-fertile and produce many seeds.

Fruits and Seeds.—The fruit is a three-chambered capsule which, in some species, discharges the seeds with considerable force. The seeds contain endosperm and a straight embryo.

Economic Significance.—The Violaceae are chiefly valued for their flowers, the violets and the pansies, both of which are found in nearly all climates, even beyond the arctic circle. There are at least 200 species of *Viola*, and through hybridization and selection hundreds of varieties have been produced. The violets are mostly in solid colors of many shades, but in the pansies broken colors are the rule and these are of innumerable patterns.

31. CACTACEAE. Cactus Family

About 40 genera and 1,000 species, restricted almost exclusively to North and South America and most numerous in Mexico and Central America. Only one genus, *Rhipsalis*, is native to the

eastern hemisphere. This is composed of epiphytes and is found in the tropics of Asia and Africa. The cacti are typically xerophytic and tropical but extend through the semi-arid region of the west into southern Canada.

Familiar Examples.—Few cacti grow wild in the United States excepting in the far west, where the prickly pear (*Opuntia* spp.) is a common desert plant, and in the extreme southwest where many species are abundant. Night-blooming cereus (*Hylocereus undatus* Britt. & Rose) is often grown in dooryards, and crab cactus (*Zygocactus truncatus* Schum.), rat-tail cactus (*Aporocactus flagelliformis* Lem.), and many other species are commonly found in greenhouses and conservatories.

Stems and Roots.—Cactus stems are peculiar in appearance. They are thick and fleshy, and while some grow 50 to 60 feet high they can hardly be called shrubs or trees because of their texture. They are subglobose to cylindrical or flattened and most of them have prominent vertical ridges. Almost invariably they are spiny, sometimes extremely so, the spines growing from rounded cushions or tubercles composed of a combination of leaf base and rudimentary branch. In many cases at least, the larger spines, and perhaps all, should be looked upon as specialized leaf parts. The root system is small and shallow for xerophytic plants of their size.

Leaves.—Cacti are commonly described as leafless, the leaves being reduced to spines as stated above. In *Opuntia* a few small awl-shaped leaves develop and fall when very young. The function of photosynthesis is assumed by the dark green stems. Two tropical genera show a mesophytic structure, with slender branches and broad simple leaves.

Inflorescences and Flowers.—The flowers are solitary, large, and showy. Generally they are regular or nearly so, but in some species the sepals are petaloid, or the petals sepaloid, making the two intergrading or indistinguishable. Perianth segments and stamens are generally numerous with epigynous insertion on the inferior ovary. The pistil is composed of several closely united carpels with one seed chamber.

Fruits and Seeds.—The fruit is a rather compact, many-seeded berry. The seeds contain endosperm in varying amounts. The embryo varies from straight to semi-circular.

Economic Significance.—The Cactaceae have more scientific interest than economic importance. Their peculiar forms and

gorgeous flowers have given them some recognition in the greenhouse, and the traveler in the American tropics is impressed with their adaptability to their environment. The fruits of some species are sweet and of good flavor, but their use is rather local. That the stems of some are nutritious is well established, but their compact form, vicious spines, and sometimes disagreeable taste have given them general immunity from consumption by live-

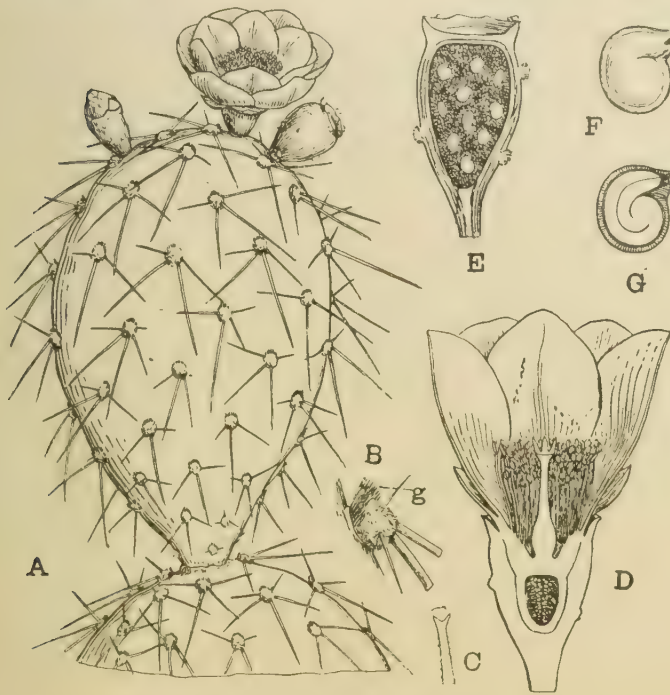


FIG. 38.—*Opuntia Tuna* (Cactaceae). A, portion of stem with bud, flower, and fruit. B, cluster of spines. C, single bristle. D, longitudinal section of flower. E, longitudinal section of fruit. F, seed (external). G, seed (internal). (After Rendle.)

stock. Even that recent introduction, the spineless cactus, is but a partial success. In Mexico cacti are sometimes grown for hedges.

32. ONAGRACEAE. Evening Primrose Family

There are about 38 genera and 470 species, rather widely distributed, but most abundant in the sub tropical portions of the western hemisphere.

Familiar Examples.—Fuchsia (*Fuchsia* spp.), evening primrose (*Oenothera* spp.), and willow-herb or fire-weed (*Epilobium angustifolium* L.) are well-known examples of this family.

Stems and Roots.—The Onagraceae are nearly all annual herbs with a few biennials and occasional shrubby forms.

Leaves.—The leaves may be alternate or opposite, and are simple and usually entire or nearly so, with stipules reduced to small glands or absent.

Inflorescences and Flowers.—The flowers are often very large, solitary and axillary, or borne in racemes. They are bisexual, and mostly regular and 4-merous, although the number of sepals, petals, and stamens varies from two to nine. The sepals are borne on a tube which is adherent at its base to the ovary and often extends far above it. The distinct petals and sepals are inserted in the throat of the calyx tube. The pistil is composed of two to six carpels, generally four. Its ovary is inferior or nearly so, and the style is often very long to reach the length of the calyx tube.

Fruits and Seeds.—The fruit is generally a capsule containing many seeds, which are without endosperm and contain a straight or nearly straight embryo. In *Epilobium* the seeds bear a tuft of long silky hairs at one end, and these effectively aid in seed distribution.

Economic Significance.—As a rule the Onagraceae are unpalatable to livestock, but the fire-weeds are an exception and are valuable forage plants where available. They are also important honey plants, and in burned-over areas they often spring up in great abundance. Many beautiful wild and cultivated plants belong to this family. These include the evening primroses, fuchsias, and Clarkias.

33. UMBELLIFERAE (AMMIACEAE). Carrot Family

The family Umbelliferae is a rather large one, containing about 270 genera and 2,700 species. They are widely distributed but most abundant in the north temperate zone.

Familiar Examples.—Familiar examples are carrot (*Daucus Carota* var. *sativa* DC.), parsnip (*Pastinaca sativa* L.), parsley (*Petroselinum hortense* Hoffm.), and celery (*Apium graveolens* L.).

Stems and Roots.—The Umbelliferae are herbaceous, with a predominance of perennials, although biennials and annuals are numerous also. In many species the nodes are conspicuously

enlarged and the internodes are hollow. Commonly the stems are vertically ridged. The roots are large—tap, fascicled, or irregular—and often fleshy. Rootstocks are found in some species.

Leaves.—With few exceptions the leaves are pinnately compound and often decompound. The petiole is often swollen, even hollow at the base, and sheathing the stem. Stipules are rare, and when present they are small or membranous. The arrangement is alternate.

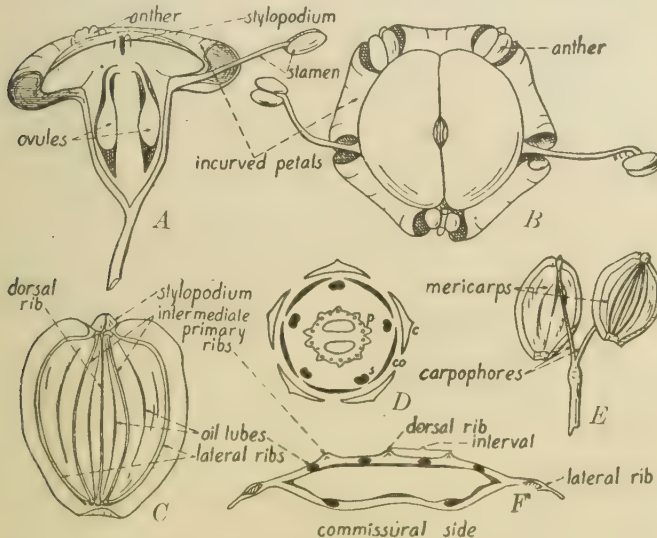


FIG. 39.—*Pastinaca sativa* (Umbelliferae). A, longitudinal section of flower. B, top view of same. C, dorsal view of mericarp. D, floral diagram. E, fruit. F, cross section of mericarp. (After Robbins.)

Inflorescences and Flowers.—As would be expected from the name of the family, the inflorescence is usually an umbel. It is reduced to a single flower in some species of *Azorella* and *Hydrocotyle*, however, and forms a compact head in *Eryngium*. The flowers are small, regular, and bisexual. They are 5-merous except for the pistil which is bicarpellate. The order of development of the floral organs is peculiar, *viz.*: stamens, petals, sepals, and pistil. The calyx may be reduced to a few minute scales or to a narrow circular ridge. The insertion is epigynous.

Fruits and Seeds.—The fruit is characteristic of the family and is called a schizocarp. At the top, where the style was attached,

is an elevation, the stylopodium, which is the remains of a nectary. In dehiscence the two carpels, called mericarps, separate, the line of division being called the commissure. For a time



FIG. 40.—*Cicuta occidentalis* Greene. (Umbelliferae.) Water hemlock or water parsnip. This common name applies to the various species of *Cicuta*, probably all of which are poisonous from the presence of cicutoxin. They are widely distributed, and grow chiefly in marshy places and along streams and ditches. (One-eighth natural size.)

after dehiscence each mericarp hangs suspended by a slender stalk, the carpophore. Each mericarp contains a single seed

which is adherent to it, with the result that the whole structure is commonly called a seed. The fruit is variously marked with ribs, grooves, bristles, and oil tubes, which are much used for generic and specific distinctions. The seed has a hard oily endosperm.

Economic Significance.—The Umbelliferae are important chiefly for vegetables, volatile oils, and drugs. Of the vegetables, carrots, parsnips, and celery are the chief members. The biennial species store much food in fleshy tap roots the first year of their growth, and if these are grown a second season this food is used in fruiting. Volatile oils, resins, etc., are produced in glands in the bark, leaves, and fruits, and give the plants their fragrance. Caraway (*Carum Carvi* L.), dill (*Anethum graveolens* L.), and anise (*Pimpinella Anisum* L.) are used for flavoring. Angelica, carum oil, conium, asafetida, and numerous other medicinal products are obtained from this family.

The family Umbelliferae is one of the most important for forage plants. Among the members worthy of mention are the angelicas (*Angelica* spp.), cow parsnip (*Heracleum lanatum* Michx.), wild parsley or carrot (*Leptotaenia* spp.), and sweet-cicely (*Osmorhiza* spp.). Several species are poisonous. Most important among these is water hemlock, cowbane, or poison parsnip (*Cicuta* spp.), and conium (*Conium* spp.). The fleshy roots of these plants are very deadly to all kinds of livestock, and have many times been fatal to man. The poisonous principle is an alkaloid, cicutin. There is a popular belief that if the common garden parsnip escapes from cultivation it becomes poisonous. This is an error based on wrong identification. It has been abundantly proven that parsnip run wild is harmless.

34. CORNACEAE. Dogwood Family

Of the Cornaceae there are 10 genera but only about 115 species. These are found mostly in the north temperate zone, with a little extension into South America. There are indications that they originated in what is now northern Canada or Greenland and spread to all the continents of the northern hemisphere. Their lineage dates back to the Cretaceous period, but they have never been a conspicuous part of the earth's flora. At present they are found scattered through forests of other trees and along the banks of streams over a wide area.

Familiar Examples.—Flowering dogwood (*Cornus florida* L.), Pacific dogwood (*Cornus Nuttallii* Aud.), the common small-flowered dogwood (*Cornus* spp.), black gum (*Nyssa sylvatica* Marsh), and tupelo (*Nyssa* spp.), are representative examples.

Stems and Roots.—The Cornaceae are mostly shrubs, but the Pacific dogwood is a tree, sometimes 60 feet high and 1 foot in diameter. Several species are conspicuous for the color of their bark, which is green in some but deep red in others. The wood

of the eastern flowering dogwood is exceedingly hard and close grained. The pepperidge or sour gum trees tend to become hollow as they grow older and are often inhabited by wild bees, hence the use of the term "gum" as a colloquial name for a bee-hive.

Leaves.—The leaves are simple and usually entire, petiolate, and exstipulate. Their arrangement is generally opposite.

Inflorescences and Flowers. The inflorescence is usually a cyme or a panicle, but it may be a head with four to six large petaloid bracts at the base. The flowers are small, regular, and mostly bisexual and 4-merous, except for the bicarpellate ovary. The insertion



FIG. 41.—*Cornus Nuttallii* (Cornaceae). A, flower cluster encircled by petal-like bracts. B, single flower. C, cluster of fruits. (After Jepson.)

is epigynous. In the so-called flowering dogwood, the inflorescence is practically a head of tiny flowers inside of a whorl of four, five, or six large, white or pink, showy bracts, which are commonly mistaken for petals. The whole effect is that of a single flower 3 to 4 inches in diameter.

Fruits and Seeds.—The fruit is a small berry-like drupelet which at maturity may be red, white, blue, or green. It contains one or two seeds with copious endosperm. The embryo is often small.

Economic Significance.—In two respects the Cornaceae are valuable. The dogwoods are ornamental shrubs, some prized

for their bright red bark, which gives them a striking appearance through the winter when the leaves are gone, and some for the large, showy, petal-like flower bracts. These "false flowers," as they may be called, appear in the undergrowth of the forest early in the season and are of striking beauty, some of them being 3 inches or more in diameter. The tupelo trees of south-eastern United States yield a great abundance of nectar which makes honey of a high quality.



FIG. 42.—*Monotropa uniflora* (left), and *Monotropa Hypopitys* (right), (Monotropaceae). (After Dixon.)

35. MONOTROPACEAE. Indian Pipe Family

An interesting little family of about 9 genera and 12 species, found mostly in North America. By some authorities they are included in the wintergreen family (Pyrolaceae), and these in turn are frequently included in the large heath family (Ericaceae). The relationships are undoubtedly close.

Familiar Examples.—The Monotropaceae are so rare in most parts of the country that many people have never seen them. The best known are Indian-pipe (*Monotropa uniflora* L.), pine sap (*Monotropa Hypopitys* L.), and pine drops (*Pterospora andromedea* Nutt.).

Stems and Roots.—The Monotropaceae are herbaceous annuals, lacking chlorophyll, waxy white, often tinged with pink, red, or purple when young, but drying to a dark brown. They are saprophytic, or a few species, such as *Pterospora andromedea* Nutt., are root parasites.

Leaves.—The leaves are small, simple, entire, sessile, exstipulate, and without chlorophyll. Often they are reduced to mere scales. Their arrangement is alternate.

Inflorescences and Flowers.—The flowers are borne in racemes or are solitary. They are small, regular, and bisexual. In *Monotropa* they are polypetalous; in *Pterospora* and *Monotropsis* gamopetalous; in *Allotropa* they are wanting. The parts are typically 5-merous, but two to six sepals and petals, six to twelve stamens, and four to six carpels are sometimes found. The insertion is hypogynous.

Fruits and Seeds.—The fruit is a tiny capsule with numerous seeds. The seed contains a fleshy endosperm and a straight minute embryo.

Economic Significance.—The family has no importance excepting for its scientific interest.

36. ERICACEAE. Heath Family

The Ericaceae as here treated, exclusive of the Pyrolaceae, Monotropaceae, and Vacciniaceae, have about 60 genera and 1,100 species. They are world-wide in distribution, with especial concentration in Africa and southeastern Asia. They are commonly found as an undergrowth in forests, but some grow in the open.

Familiar Examples.—Well-known examples are trailing arbutus (*Epigaea repens* L.), spicy or creeping wintergreen or checkerberry (*Gaultheria procumbens* L.)—the edible species, not to be confused with the wintergreens of the Pyrolaceae—kinnikinnick or bearberry (*Arctostaphylos Uva-ursi* (L.) Spreng.), laurel (*Kalmia* spp.), rhododendron (*Rhododendron* spp.), and azalea (*Azalea* spp.).



FIG. 43.—*Kalmia latifolia* L. (Ericaceae). Mountain laurel. The laurels, of which there are many, are widely distributed throughout the wooded regions of the country, where they form a conspicuous portion of the undergrowth. (Two-thirds natural size.) (After Dixon.)

Stems and Roots.—This family is essentially shrubby, with a considerable number of woody vines and perennial herbs and a few trees.

Leaves.—The leaves are simple, often entire and sessile, exstipulate, and in most species evergreen. The leaf arrangement is commonly alternate, but may be opposite or whorled.

Inflorescences and Flowers.—The inflorescence is varied—racemes, spikes, umbels, and solitary flowers being common. The flowers are polypetalous, or more often gamopetalous, and generally regular and bisexual. They are mostly 5-merous or 4-merous, with stamens double the number of petals and sepals. The insertion is hypogynous.

Fruits and Seeds.—The fruit is a capsule, berry, or drupe, with a straight embryo and endospermous seeds.

Economic Significance.—For flowering shrubs no family can compare with the Ericaceae. Their fragrant flowers, often in great clusters, and their glossy evergreen leaves give them a peculiar charm. They grow in great profusion out of doors, and are extensively raised under glass. Considerable honey is obtained from various members of the family, and sourwood (*Oxydendrum arboreum* (L.) DC.) is reputed to be the most valuable honey-producing plant in the southeastern states, both for quantity and quality. The family has little forage value, but a considerable number of species are poisonous to livestock from the presence of andromedotoxin. The poisonous members include the laurels (*Kalmia latifolia* L., *K. angustifolia* L., *Ledum glandulosum* Nutt., *Leucothoe Davisiae* Torr., *Menziesia glabella* Gray, *Rhododendron albiflorum* Hook., *R. occidentale* Gray) and probably other species. In general they are unpalatable, but if feed is scarce sheep may be forced to eat them with fatal results.

37. VACCINIACEAE. Huckleberry Family

The Vacciniaceae have been separated from the Ericaceae because of their inferior ovaries. They include about 20 genera and 300 species and are widely distributed in temperate climates. They are found mostly in open spots in timbered country, and some species grow best in swamps.

Familiar Examples.—Huckleberries (*Gaylussacia* spp.), blueberries or bilberries (*Vaccinium* spp.), and cranberries (*Vaccinium Oxycoccus* L. and *Vaccinium macrocarpon* Ait.) are well-known members of the Vacciniaceae.

Stems and Roots.—All members of the family are woody—shrubs, vines, or, in a few cases, small trees.

Leaves.—The leaves are simple, usually entire and sessile, exstipulate, and sometimes evergreen. The arrangement is alternate.

Inflorescences and Flowers.—The flowers are in small compact racemes or solitary. They are small, regular, bisexual, and usually polypetalous. The sepals, petals, and carpels are four or five each, and the stamens twice as many. The carpels are firmly united and surrounded by a hypanthium on which the epigynous stamens, petals, and sepals are attached.

Fruits and Seeds.—The fruit is usually a berry, containing many small endospermous seeds with straight embryos.

Economic Significance.—The Vacciniaceae are chiefly important for their delicious berries. The huckleberries and blueberries are found wild in great quantities and are eaten fresh or in pies and other pastry. The cranberries, being good keepers, can be shipped fresh for use throughout the winter when fruit is scarce, and their fine tart flavor brings them into great demand. Some of the species have a limited forage value.

38. GENTIANACEAE. Gentian Family

If the Menyanthaceae be excluded from the Gentianaceae, there remain in this family about 65 genera and 700 species. They are of wide geographic distribution, but are best known in temperate regions.

Familiar Examples.—The gentians (*Gentiana* spp.) and centaury (*Centaurium* spp.) are examples.

Stems and Roots.—The members of the Gentianaceae are practically all herbaceous, the perennial species often producing rhizomes. The juice of the plant is generally bitter to the taste.

Leaves.—The leaves are opposite and exstipulate, and mostly entire and sessile. In a few saprophytic species they are much reduced and destitute of chlorophyll, or nearly so.

Inflorescences and Flowers.—In some species the flowers are terminal and solitary, but more commonly they are in cymes. The flowers are typically bisexual and 5-merous, but the sepals, petals, and stamens may be reduced to four, or increased to as many as twelve, and the pistil is bicarpellate. The calyx and corolla are regular, of more or less united segments. The

stamens are attached to the throat of the corolla. The ovary is superior in most species.

Fruits and Seeds.—The fruit is generally a many-seeded, dehiscent capsule. The seed, as a rule, has a copious endosperm with a small embryo, but exceptions are found in some saprophytic species.

Economic Significance.—Formerly much value was set upon the medicinal properties of various members of this family. Almost without exception they are so bitter that they are unpalatable to livestock. Probably their greatest value lies in the beauty and abundance of their flowers.

39. ASCLEPIADACEAE. Milkweed Family

There are about 280 genera and 1,800 species of world-wide distribution but most abundant in the subtropics and tropics.

Familiar Examples.—Milkweed or silkweed (*Asclepias* spp.), pleurisy-root (*A. tuberosa* L.), wax plant (*Hoya carnosa* R. Br.), and carrion-flower (*Stapelia variegata* L.) are examples of the Asclepiadaceae.

Stems and Roots.—The species found in the United States are mostly perennial herbs, but in warmer climates shrubs and shrubby vines predominate and a few species become small trees. The fibrovascular bundles are bicollateral in type, and the plants are filled with long, branching, laticiferous tubes which contain a starchy and albuminous milky juice. Rootstocks are common and these may be long and slender, for vegetative propagation, or fleshy and even tuberous for food storage.

Leaves.—The leaves are simple and generally entire, exstipulate, and opposite in most species.

Inflorescences and Flowers.—The inflorescence is mostly umbellate, but sometimes cymose or racemose. The flowers are rather small, regular, bisexual, and gamopetalous. They are 5-merous, excepting the pistil which is bicarpellate, with a superior ovary. The filaments attach to the base of the corolla and are often united to form a sheath or column around the pistil, the anthers being pressed close to the style. Each stamen bears, on the side away from the pistil, an appendage which enfolds the anther like a hood. Similar appendages are borne on the petals in some species. These appendages collectively make up the corona.

Fruits and Seeds.—The fruit is composed of two follicles which may be close together or divergent. In *Asclepias* and some other genera they are large and pod-like. Each follicle contains many seeds which commonly bear tufts of long, white, silky hair. The embryo is large and straight, and the endosperm hard and thin.

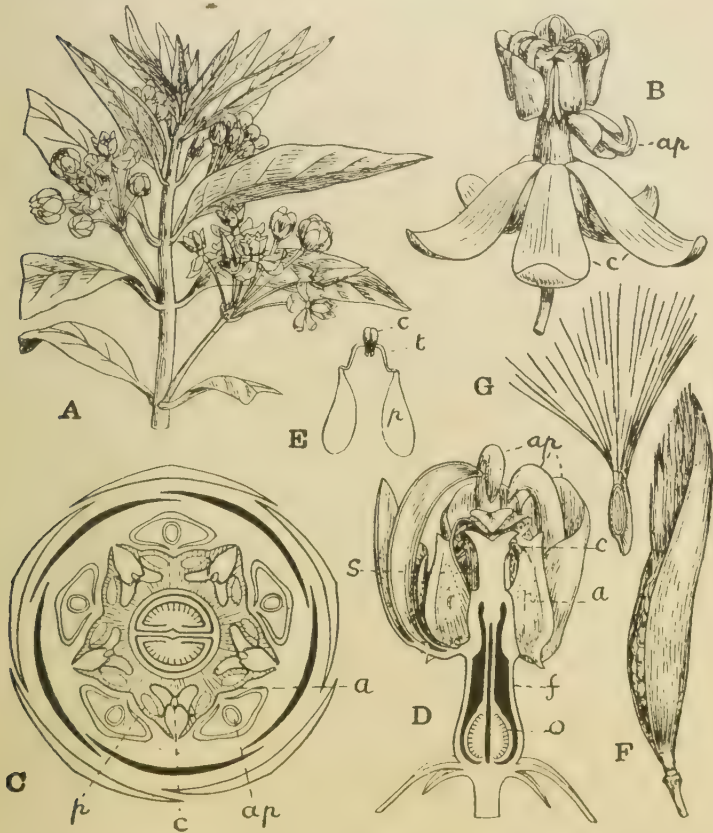


FIG. 44.—*Asclepias curassavica* (Asclepiadaceae). *A*, inflorescences. *B*, single flower. *C*, floral diagram. *D*, longitudinal section of flower. *E*, pollinium. *F*, fruit. *G*, seed. (After Rendle.)

Economic Significance.—For the size of the family the Asclepiadaceae are relatively unimportant. They are unpalatable to livestock and a few species of *Asclepias* are rather troublesome as weeds.



FIG. 45.—*Asclepias Mexicana* Cav. (Asclepiadaceae). Mexican whorled milkweed. The milkweeds of this genus, several of which are poisonous, are widely distributed, but are especially abundant on the open foothills of the western mountains. (One-half natural size.) (After Marsh.)

40. CONVULVACEAE. Morning Glory Family

About 45 genera and 1,000 species, most abundant in the tropics and subtropics, but well known throughout the world.

Familiar Examples.—Familiar examples of the Convolvulaceae are morning glory (*Ipomoea* spp.), bindweed (*Convolvulus* spp.), some of which are often called morning glory, moon flower (*Calonyction aculeatum* House), and sweet potato (*Ipomoea Batatas* Lam.).

Stems and Roots.—Most of the Convolvulaceae are twining herbaceous vines, but in the tropics some are shrubs, and a few are small trees. Often the vines are long and profuse, completely entangling the adjacent vegetation. A milky juice is not uncommon. The root system is very large. Sometimes the roots are long and slender, as in *Convolvulus arvensis* L., where they serve the purpose of vegetative propagation. Sometimes they are thick and fleshy and of huge size, as in *Ipomoea pandurata* (L.) Meyer and *I. leptophylla* Torr., where they store great quantities of food. Thick tuberous rhizomes are found in *Convolvulus Scammonia*.

Leaves.—The leaves are simple, exstipulate, and alternately arranged.

Inflorescences and Flowers.—The flowers are solitary, or in small cymes. They are gamopetalous, regular, generally large and bell shaped, and 5-merous with a bicarpellate or tricarpellate pistil. The calyx and corolla are inserted on the receptacle, and the stamens on the corolla tube, leaving the ovary free. There are from one to three long styles.

Fruits and Seeds.—The fruit is a capsule with two or three chambers, or, by false partitions, apparently twice the number. Each chamber encloses one or two seeds, each containing a more or less curved embryo and scanty endosperm.

Economic Significance.—The sweet potato is one of our most important vegetables. The fleshy roots are produced in abundance, are rich in starch, and of fine flavor. Of subtropical origin, they grow best in the south, although some varieties succeed in the middle states. The term "yam" is sometimes applied to the wetter-fleshed varieties of sweet potatoes, but it must be remembered that the true or Chinese yam is a monocotyledonous plant (*Dioscorea Batatas* Deene.).

The vigorously growing vines and large, many-colored flowers make the morning glories very desirable for trellises on porches, fences, etc. Unfortunately the flowers wither quickly when cut.

A few members are pernicious weeds, especially the small or European bindweed (*Convolvulus arvensis* L.). The family has very little forage value, although not poisonous.

41. CUSCUTACEAE. Dodder Family

The dodders are often included under the Convolvulaceae. There is but one genus, *Cuscuta*, with about 100 species of wide distribution.

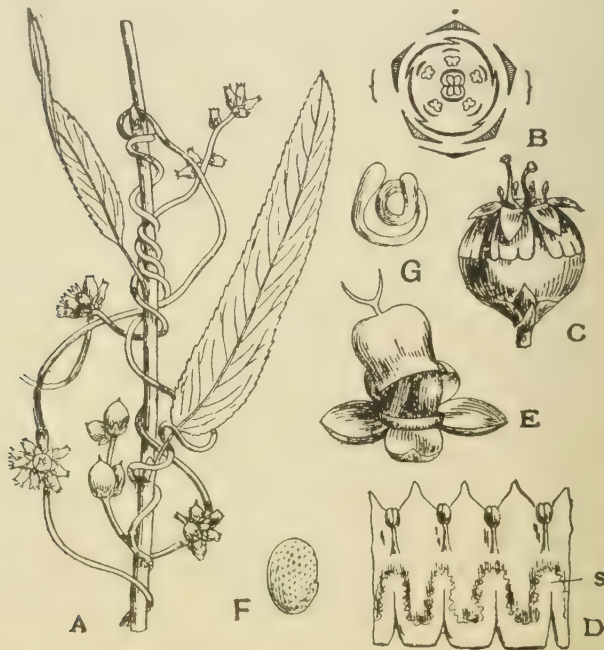


FIG. 46.—*Cuscuta* (Cuscutaceae). *A*, parasite on willow. *B*, floral diagram. *C*, fruit. *D*, corolla opened. *E*, fruit dehiscing. *F*, seed. *G*, embryo. (*A*, *E*, and *F* after Peter. *B*, after Eichler. *C*, after Hooker. *D*, after Reichenbach. *G*, after Nees.) (Arranged by Rendle.)

Familiar Examples.—Dodders of clover, alfalfa, flax, hazel, and members of the Chenopodiaceae are examples. They are also called love-vine and coral-vine.

Stems and Roots.—The dodders are all slender herbaceous vines. They start from seeds in the soil, but the young vines, if favored by fortune, soon find suitable plants which they attack as parasites. Adventitious roots act as haustoria and penetrate the host for nourishment, after which the older basal part of the

stem next the soil shrivels, and the plants become completely parasitic. They lack chlorophyll and are white or yellowish in color—in *C. sabina* Englm. rich golden or orange. The attacking plants branch freely and grow rapidly from branch to branch of the host and adjacent hosts until all are entangled in a wiry mass. Some of the dodders can attack only one species or a few related species. Others attack unrelated plants. Unless they find a suitable host, all dodders must die when the food supply of the seed is exhausted, as they cannot live on the soil and air alone, *i.e.*, they are not autophytic.

Leaves.—The leaves are reduced to minute scales having an alternate arrangement.

Inflorescences and Flowers.—The flowers are borne in dense cymose clusters. They are small, regular, bisexual, and gamopetalous. Except for the bicarpellate pistil they are 5-merous. Generally there are five small scales attached to the corolla tube below the insertion of the stamens.

Fruits and Seeds.—The fruit is a one- to four-seeded capsule, generally indehiscent. The seeds have abundant endosperm, a more or less curved embryo, but no cotyledons.

Economic Significance.—Dodders are sometimes troublesome in cultivated crops which they bind together and make difficult to harvest, besides reducing the yield.

42. BORAGINACEAE. Borage Family

The Boraginaceae are prominently represented throughout the world with about 85 genera and 1,500 species.

Familiar Examples.—Bluebells (*Mertensia* spp.), forget-me-not (*Myosotis* spp.), beggar's lice (*Lapula* spp.), and heliotrope (*Heliotropium peruvianum* L.) are examples of the borage family.

Leaves.—The leaves are simple, exstipulate, and usually narrow, sessile, and alternate, or the lower ones opposite and petiolate. In most species they are pubescent or even densely hairy.

Stems and Roots.—Most of the borage family are perennial herbs, a few being shrubs or trees.

Inflorescences and Flowers.—The inflorescence is characteristically a scorpioid cyme which uncoils as the flowers open. The flowers are generally regular and bisexual. The calyx and corolla are tubular and often much elongated. The flowers are 5-merous, except the pistil, which is bicarpellate but usually

with a four-lobed superior ovary. The stamens are inserted in the throat of the corolla.

Fruits and Seeds.—The fruit consists of four nutlets or drupelets which may, however, remain united in a single body. Some species have little or no endosperm and others much. In some the embryo is straight and in others curved.

Economic Significance.—The flowers, which are generally bluish or purple, are often highly decorative. Many species of *Mertensia* are excellent forage plants and grow abundantly around springs and in marshy places in mountainous regions.

43. LABIATAE. Mint Family

The mints are so distinctive in appearance and fragrance that they have been well recognized for centuries. There are about 170 genera and 3,000 species of world-wide distribution.

Familiar Examples.—Familiar examples are peppermint (*Mentha piperita* L.), catnip (*Nepeta Cataria* L.), hoarhound (*Marrubium vulgare* L.), thyme (*Thymus vulgaris* L.), sage (*Salvia* spp.)—not to be confused with “sage brush” (*Artemisia* spp.) of the family Compositae—skull cap (*Scutellaria* spp.), and coleus (*Coleus* spp.).

Stems and Roots.—The Labiatae are mostly herbaceous, but a considerable number of shrubs and a few small trees are found in the tropics. The stems of the herbaceous species are commonly square.

Leaves.—The leaves are simple, exstipulate, and opposite, or, in a few species, whorled. They are abundantly supplied with glands secreting volatile oils.

Inflorescences and Flowers.—The flowers are generally borne in small axillary cymes, which by their arrangement along the upper part of the stem often give the effect of a raceme. They are bisexual, gamopetalous, more or less irregular, and often two-lipped. There are four or five sepals and petals, and four or two stamens in pairs. If there are but two they are often supplemented by two staminodes. The pistil is bicarpellate with a superior ovary.

Fruits and Seeds.—The deeply two-lobed capsular fruit breaks up without true dehiscence into four nutlets. The seeds have little or no endosperm and the embryo is usually straight.

Economic Significance.—The Labiatae are chiefly valuable for their volatile oils, which are used for flavoring and for medicine.

These are quite numerous and the list given above under familiar examples is but representative. Additional products of medicinal value are marrubium, hedeoma, and scutellaria. A few of the plants, such as coleus, are ornamental. The Labiatae quite generally yield nectar in abundance. The sages of California, especially the black sage (*Salvia mellifera* Greene), are among the heaviest producers, and the quality of the honey is excellent.

44. SOLANACEAE. Potato Family

The potato family is one of the best known, containing about 85 genera and 1,800 species. They are of wide distribution, especially abundant in the tropics and subtropics.

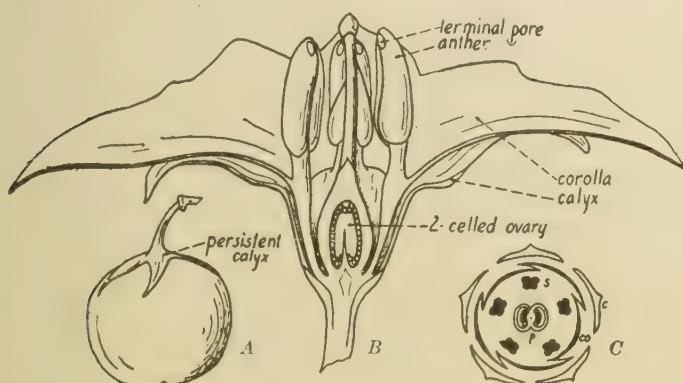


FIG. 47.—*Solanum tuberosum* (Solanaceae). A, fruit. B, longitudinal section of flower. C, floral diagram. (After Robbins.)

Familiar Examples.—Examples of the Solanaceae are potato (*Solanum tuberosum* L.), tomato (*Lycopersicon esculentum* Mill.), eggplant (*Solanum Melongena* L.), ground cherry (*Physalis* spp.), red pepper (*Capsicum frutescens* L.), and tobacco (*Nicotiana Tabacum* L.).

Stems and Roots.—The Solanaceae of the temperate zones are mostly herbaceous, but in the tropics many shrubby forms are found and a few small trees. The production of underground tubers, such as those of the potato, is exceptional.

Leaves.—The leaves are mostly simple, but sometimes deeply cleft, and in a few species pinnately compound. They are exstipulate and usually alternate. They are evergreen in a few genera, as *Lycium*.

Inflorescences and Flowers.—The inflorescence is generally cymose or racemose, but solitary flowers are not unusual. The flowers are often large and showy, regular or nearly so, gamopetalous, and bisexual. There are five each of sepals, petals, and stamens, and a bicarpellate pistil with a superior ovary and, usually, a long style.

Fruits and Seeds.—The fruit is usually a berry, sometimes of very large size, as in tomato and eggplant. In those species where the pericarp does not develop a fleshy pulp, the fruit is a capsule. There are numerous seeds with fleshy endosperm and a curved or annular embryo. In some genera, such as *Physalis*, the persistent calyx develops a bladdery husk about the fruit.

Economic Significance.—The Solanaceae are of more than ordinary importance to the human race. They contribute heavily to the food supply through the potato, tomato, and egg plant. In the United States and Europe the potato ranks second to wheat. Tobacco is a major crop over large areas of the country, nearly two million acres being devoted to it, although its value is debatable. Powerful drugs, mostly of a narcotic nature, and some of great value in medicine are characteristic of the family. The alkaloid solanin is found in greater or less quantity in many species, even in potatoes and tomatoes. Atropin, belladonna, capsicum, hyocyamus, scopolia, and stramonium are all obtained from this family. Some of the members are quite poisonous, as the deadly nightshade (*Solanum nigrum* L.). Among the weeds belonging to this family, the jimson weed (*Datura Stramonium* L.) is probably the most troublesome.

The large flowers and brightly colored berries make many species very attractive for flower gardens and dooryards. Among those worthy of mention are petunia (*Petunia hybrida* Vilm.), jessamine (*Cestrum* spp.), flowering tobacco (*Nicotiana* spp.), and Japanese matrimony vine (*Lycium chinense* Mill.).

45. SCROPHULARIACEAE. Figwort Family

Of the Scrophulariaceae there are about 205 genera and 2,600 species. They are widely distributed but most abundant in temperate zones.

Familiar Examples.—Examples are snapdragon (*Antirrhinum majus* L.), butter-and-eggs or toad-flax (*Linaria vulgaris* Hill), beard-tongue (*Penstemon* spp.), monkey flower (*Mimulus* spp.), purple fox-glove (*Digitalis purpurea* L.), mullein (*Verbascum*

Thapsus L.), and Indian paint brush or painted cup (*Castilleja* spp.).

Stems and Roots.—The Scrophulariaceae are mostly herbaceous, but a few are shrubs or trees. The tendency to degenerate into a more or less complete parasite is found in about fifteen per cent of the genera and species. The method of parasitism is similar to that found in the Orobanchaceae, namely the roots from the germinating seeds attack the roots of various host plants. As illustrating the different degrees of parasitism, *Gerardia flava* obtains very little of its food from the host and can live independently in its absence; *Pedicularis capitata* and *Odontites rubra* are half-parasites with small green leaves and terrestrial roots; *G. aphylla* takes most of its food from the host plant and has reduced pale leaves; while species of *Harveya* and *Hyobanche* are wholly parasitic, destitute of chlorophyll, and bear scale-like leaves only.

Leaves.—The leaves are exstipulate and mostly simple. Their arrangement on the stem may be alternate, opposite, or whorled, and some of *Antirrhinum* have the lower leaves opposite and the upper leaves on the same stem spiral. The leaves on the parasitic species are more or less reduced and poorly supplied with chlorophyll.

Inflorescences and Flowers.—The inflorescences are variable, but racemes are very common. The flowers are bisexual, gamopetalous, and more or less irregular—usually two-lipped. There are four or five united sepals, five united petals, two, four, or five stamens, and a bicarpellate pistil. The stamens are typically five, four of them in pairs of unequal length (didyna-



FIG. 48. *Mimulus guttatus* (Scrophulariaceae). *a*, flowering branch. *b*, leaves. *c*, pistil. *d*, fruit (external). *e*, fruit (cross section.) (After Jepson.)

mous), but some have been reduced to staminodes or lost. The ovary is superior, and the stamens are inserted on the corolla tube.

Fruits and Seeds.—The fruit is generally a capsule bearing many endospermous seeds, with straight or slightly curved embryos.

Economic Significance.—The importance of the Scrophulariaceae is rather limited. As forage plants most of the members are unpalatable and those that are relished do not recover well when cropped off. Their greatest value lies in their flowers, which show considerable variety of size, form, and color, and, as in the case of the Indian paint brush, are supplemented by large colored bracts. Two rather important drugs are obtained from this family, digitalis and leptandra. For so large a family not many are noxious weeds. Butter-and-eggs sometimes escapes from cultivation and forms persistent troublesome patches.

46. OROBANCHACEAE. Broom-rape Family

This family consists of about 11 genera and 130 species, found mostly in the northern hemisphere. This is one of the three parasitic families of flowering plants treated in this book. The Loranthaceae, or mistletoe family, are stem parasites attacking the host directly from the seed. The Cuscutaceae, or dodder family, are stem parasites attacking the host as seedlings that start in the soil. The Orobanchaceae are root parasites that attack the roots of the host as seedlings that start in the soil. This form of parasitism is found in a few species of several other families.

Familiar Examples.—None of the members are of sufficient abundance to have become generally known. The commonest are naked broom-rape (*Orobanche uniflora* L.), clover broom-rape (*Orobanche minor* J. E. Smith), and squaw-root or cancer-root (*Conopholis americana* (L.f.) Wallr.).

Stems and Roots.—The Orobanchaceae are annual or perennial herbs, generally a few inches high, living parasitically on the roots of various host plants. Some are restricted in their parasitism to one species or genus of host plant but others can attack a wider range. It has been shown that the seeds of some species of *Orobanche* at least will not germinate except when in contact with the roots of a suitable host. The root of the parasite becomes specialized into a haustorium which penetrates the bark,



FIG. 49.—*Orobanche minor* (Orobanchaceae). Parasite growing on clover.
(After Strasburger.)

and the plant, nourished by its host, grows into the air and passes through its vegetative and reproductive stages. All parts of the plant are destitute of chlorophyll, or with mere traces, and are yellowish-white or brownish in color.

Leaves.—The leaves are reduced to simple scales with an alternate arrangement on the stem.

Inflorescences and Flowers.—The flowers may be solitary, but more often they are in terminal racemes or spikes. There are four or five united sepals, and five petals united into an irregular, often two-lipped, tube. There are four stamens in pairs, and often a fifth that is reduced to a staminode. Their insertion is perigynous. The pistil is bicarpellate with a superior ovary. In general the flower structure strongly suggests that of the *Scrophulariaceae*.

Fruits and Seeds.—The fruit is a small capsule with many tiny endospermous seeds in which the cotyledons are but slightly developed.

Economic Significance.—Some of the members do a limited amount of damage to cultivated crops—clover, tomato, hemp, etc. They are of more scientific than economic interest.

47. CAPRIFOLIACEAE. Honeysuckle Family

This family consists of about 11 genera and 340 species, found mostly in the northern hemisphere.

Familiar Examples.—The honeysuckle (*Lonicera* spp.), elderberry (*Sambucus* spp.), snowberry or buck-brush (*Symphoricarpos* spp.), and twin flower (*Linnaea borealis* L. and *L. americana* Forbes) are familiar examples.

Stems and Roots.—The *Caprifoliaceae* are predominantly shrubs with a few vines, trees, and herbs.

Leaves.—The leaves are generally simple (pinnately compound in *Sambucus*) and opposite. In some species, as in the *Loniceras* for example, the sessile pairs of upper leaves have their bases united (connate-perfoliate). Stipules are usually absent, but present in *Sambucus* and a few other genera. A few, such as twin flower, are evergreen.

Inflorescences and Flowers.—The predominant inflorescence is a cyme, but this may be variously modified by suppression of terminal (central) or marginal flowers, or by compounding, as in *Sambucus*. The flowers are bisexual, gamopetalous, and often

irregular. They are primarily 5-merous but the parts may be reduced to two, three, or four. The insertion is epigynous.

Fruits and Seeds.—The fruit is generally a berry, but sometimes a drupe or a capsule. The seed contains fleshy endosperm, and a straight embryo.

Economic Significance.—The honeysuckle family ranks very high for ornamental shrubs, both cultivated and wild. Some of the species of *Sambucus* and *Symphoricarpos* furnish considerable browse for livestock. Several species of *Symphoricarpos* are important honey-producing plants.

48. CUCURBITACEAE. Gourd Family

The Cucurbitaceae are essentially tropical and subtropical. It is hard for those who live in the northern United States to realize that there are about 100 genera and 800 species. Beyond the Canadian border only a few species can be grown out of doors at all.

Familiar Examples.—Familiar examples are pumpkin (*Cucurbita Pepo* L.), squash (*Cucurbita* spp.), cucumber (*Cucumis sativus* L.), muskmelon or cantaloup (*Cucumis Melo* L.), watermelon (*Citrullus vulgaris* Schrad.), and wild cucumber or balsam-apple (*Echinocystis lobata* (Michx.) T. & G.).

Stems and Roots.—The Cucurbitaceae are succulent, trailing or decumbent vines, usually climbing by means of tendrils. The stems of most species are hollow and five-angled with five corresponding bicollateral bundles.

Leaves.—The leaves are simple, but often deeply cleft, sometimes compound, usually exstipulate, large, and long petioled. The petioles are often hollow. The arrangement on the stem is alternate. Concerning the morphology of the tendrils there is much difference of opinion. By some they are believed to be leaves, or that the branches are leaves and the main portion stem. By others they are considered bracteoles. It is almost certain that in *Kedrostis spinosa* they are stipules, and it may be that in different genera they are of different origin.

Inflorescences and Flowers.—The flowers are usually solitary in the axils, but in the small-flowered species they may be racemose or paniculate. They are unisexual and often dioecious. In structure the flowers are quite characteristic. They are 5-merous, but with the pistil tricarpellate by reduction, and the stamens united into two pairs, accompanied by a single one.

The filaments are short, and the anthers long and slender but folded or twisted into a compact mass. The style is short, surmounted by a broad three-lobed stigma.

Fruits and Seeds.—The fruit is a pepo or gourd, rarely a capsule, often of huge size, indeed the largest of all fruits are found in this family. The seeds are numerous, generally large and flat, and with no endosperm. The embryo is straight, with large, oily cotyledons.



FIG. 50.—*Cucurbita Pepo* (Cucurbitaceae). Staminate and pistillate flowers with portion of corolla removed to show pistils and stamens. (One-half natural size.)

Economic Significance.—The Cucurbitaceae have long played an important part in the affairs of mankind. Gourds of various shapes and sizes have been extensively used as primitive vessels and utensils. The food value, delicious flavor, and abundant production of the fruits have given them a prominent place. In addition to the familiar pumpkins, squashes, and melons, numerous other kinds are found in the tropics. To some extent, wild cucumber and other vines are grown on trellises for ornamental purposes.

49. CICHORIACEAE (LIGULIFLORAE). Chicory Family

Until recently the Cichoriaceae were considered a tribe of the Compositae, and by some good authorities they are still so classified. There are about 70 genera and 1,500 species of wide geographic distribution.

Familiar Examples.—Chicory, (*Cichorium Intybus* L.), salsify or oyster plant (*Tragopogon porrifolius* L.), lettuce (*Lactuca sativa* L.), and dandelion (*Taraxacum officinale* Weber) are the most familiar examples.

Stems and Roots.—Nearly all the Cichoriaceae are herbaceous plants with a milky juice. They are deep rooted and often perennial, and some species, such as *Lactuca pulchella* (Pursh) DC. and *Sonchus arvensis* L., spread by long rootstocks.

Leaves.—The leaves are alternately arranged, simple, but often cleft to the midrib, and exstipulate.

Inflorescences and Flowers.—The inflorescence is an involucrate head. The entire inflorescence is large and showy, but the individual flowers are small. They are all bisexual, gamopetalous and ligulate, *i.e.*, irregular, with a strap-shaped extension pointing away from the center of the head. The insertion of parts is epigynous. The calyx teeth are reduced to small scales or bristles. There are five stamens with anthers united around the style. The pistil is of two carpels so closely united that they appear as one, except for the ovary lobes found in some species and the usual development of two stigmas. The ovary is one-chambered and one-ovulate.

Fruits and Seeds.—The fruit is an achene, either naked, or, more commonly, tipped with a pappus which consists of a whorl of bristles or scales—the persistent calyx. The seed is without endosperm and the embryo is straight.

Economic Significance.—The Cichoriaceae make a moderate contribution to the food supply in the form of vegetables: lettuce, salsify, chicory, dandelion greens, etc. Some members have a limited forage value. The benefits are about offset by the troublesome weeds such as dandelion, sow thistle (*Sonchus* spp.), and Chinese and blue lettuce (*Lactuca* spp.).

50. AMBROSIAACEAE. Ragweed Family

This family, like the Cichoriaceae, is often included under the Compositae. It contains only 8 genera and about 60 species, confined mostly to the western hemisphere.

Familiar Examples.—Ragweed (*Ambrosia* spp.) and cocklebur (*Xanthium* spp.) are the best-known examples.

Stems and Roots.—Nearly all members of this family are herbaceous, either annual or perennial. In *Iva axillaris* Pursh there are long rootstocks that serve the function of vegetative propagation.



FIG. 51.—*Xanthium echinatum* Murr. (Ambrosiaceae.) Cocklebur. The cockleburs are found most commonly in cultivated fields, waste places, and along the banks of streams where the burs have been deposited by the water. After the plants reach the height of a few inches, they cease to be poisonous. (One-third natural size.)

Leaves.—The leaves are simple, although sometimes much divided. The arrangement is alternate, or, in a few species, opposite toward the base. They are exstipulate.

Inflorescences and Flowers.—The inflorescence is a small head, in *Xanthium* consisting of but two flowers. In some

species, especially those of *Ambrosia*, there are many heads arranged on a central stalk, thus giving the impression of a spike or raceme. The flowers are bisexual or unisexual and occasionally dioecious. In the same head may be found both staminate and pistillate flowers, or either one alone. In the staminate flower the calyx is usually without limb and the corolla gamo-



FIG. 52.—*Xanthium echinatum* Murr. (Ambrosiaceae.) It is at this young stage, while the cotyledons still persist, that the plants are poisonous. (Natural size.)

petalous with four or five lobes. There are usually five stamens, not connate but often connivent, and inserted on the throat of the corolla tube. Usually a rudimentary pistil is present consisting of a style with an undeveloped ovary and stigma. In the pistillate flower the calyx is without limb and the corolla is absent or reduced to a minute ring. The ovary is deeply buried in the receptacle from which the styles protrude. In the bisexual flowers the perianth is not quite so much reduced as in the unisexual ones.

Fruits and Seeds.—The fruit is an achene which is without pappus but sometimes covered with involueral hooks, as in *Xanthium*, or spines, as in *Franseria*. Often two achenes are

enclosed in one bur. The seed contains a straight embryo and no endosperm.

Economic Significance.—None of the members of the Ambrosiaceae have any particular value to mankind. A considerable proportion are troublesome weeds, particularly poverty weed (*Iva axillaris* Pursh), horse ragweed or kinghead (*Ambrosia trifida* L.), and cocklebur (*Xanthium* spp.). Cocklebur is also important in some sections as a cause of livestock poisoning. The cotyledonous stage of the seedling, which is readily eaten, is poisonous to cattle, but older plants are not relished and are apparently harmless. In general the Ambrosiaceae are unpalatable to livestock. The pollen of *Ambrosia*, especially, is a frequent cause of hay fever.

51. COMPOSITAE (CARDUACEAE). Thistle Family

The largest and highest of all the families of plants is the Compositae. Exclusive of the Cichoriaceae and Ambrosiaceae, which are here treated as separate families, there are about 800 genera and 10,000 species. They are of world-wide distribution.

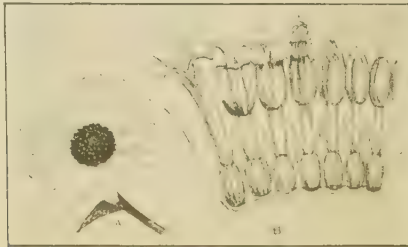


FIG. 53.—Compositae. A, inflorescence. B, longitudinal section of inflorescence, showing tubular and ray flowers.

Familiar Examples.—Familiar examples are sunflower (*Helianthus annuus* L.), aster (*Aster* spp.), goldenrod (*Solidago* spp.), Canada thistle (*Cirsium arvense* (L.) Scop.), yarrow (*Achillea Millefolium* L.), and wormwood or sage brush (*Artemisia* spp.).

Stems and Roots.—The Compositae are nearly all herbaceous, but a small proportion are shrubby, and in the tropics a few reach the stature of trees. Tubers are produced by a few species, e.g., Jerusalem artichoke (*Helianthus tuberosus* L.), and wild artichoke or Maximilian's sunflower (*H. Maximiliani* Schrad.).

Leaves.—The leaves are mostly simple, alternately arranged, and exstipulate.

Inflorescences and Flowers.—The inflorescence is a head subtended by an involucre. The flowers are varied, mostly bisexual, but frequently pistillate or neutral, *i.e.*, with both stamens and pistils aborted, and occasionally staminate. In one type of head (discoid) the corolla is small and regular (tubular) in all the flowers. In the other type (radiate) the central flowers are tubular, and those in the outer row are ligulate and generally



FIG. 54.—*Eupatorium urticifolium* Reich. White snakeroot. This plant is found in woods and pastures throughout the eastern half of the United States. (One-half natural size.) (After Hansen.)

pistillate or neutral. The insertion is epigynous and the calyx teeth reduced to scales, bristles, or a shallow cup, or they may be entirely absent. The corolla is five-toothed. The stamens are usually five in number and connate. The pistil is bicarpellate, with one chamber and one ovule.

Fruits and Seeds.—The fruit is generally a simple achene, which may be naked or plumed from the development of the pappus (calyx). The embryo is straight and there is no endosperm.

Economic Significance.—The contribution of this large family to the food supply is rather limited. Few members are eaten directly by man. Considerable use is made of the cultivated sunflower, the seeds for poultry, and the stems, leaves, and heads for ensilage. In regions too cold for corn the sunflower has become an important substitute in livestock feeding. While many species are unpalatable others are relished, and on the whole the family ranks high in forage value. Poisonous members are not generally troublesome, although white snakeroot (*Eupatorium urticaefolium* Reich.), western sneezeweed (*Dugaldia Hoopesii* (A. Gray) Rydb.) some of the goldenrods (*Solidago spectabilis*, and *S. concinna* A. Nels.) are known to cause some losses of livestock. Of these, white snake root is of the greatest interest as it has been shown to be the cause of the mysterious milk sickness or trembles which affects cattle especially, but also horses and sheep, and people drinking milk from poisoned cows.

The flower-like heads have given the family a prominent place for decorative purposes. That the great heads of dahlias, chrysanthemums, asters, and daisies are thought of as flowers rather than inflorescences does not detract from their beauty. To these names may be added those of the rudbeckias, goldenrods, and a host of wild composites.

In number of official drugs produced the Compositae are among the highest, although these are not of as much value as those of the Solanaceae, for example.

Several species are important as weeds, the worst being the Canada thistle and the wild sunflower. Several kinds of sage brush (*Artemisia* spp.) shed an abundance of pollen that causes hay fever.

CHAPTER XIV

FAMILIES OF MONOCOTYLEDONS

In number of families, genera, and species the monocotyledons are not nearly so numerous as the dicotyledons, but certain families, for example the Gramineae, are of outstanding importance.

Origin.—The origin of the monocotyledons has been the subject of considerable controversy.¹ For some years they were thought to be more primitive than the dicotyledons and probably ancestral to them. This belief, however, is out of harmony with both morphological and paleontological evidence. It is now generally conceded that the dicotyledons are the older and gave rise to the monocotyledons. The prevailing belief today is that the monocotyledons are an offshoot of the primitive dicotyledons back in the early part of the Mesozoic era, and that they are monophyletic, *i.e.*, of one origin, the first monocotyledons being ancestral to all the others. A third and newer conception is that the monocotyledons are not a simple monophyletic group but are polyphyletic, different members having sprung at different times from distinctly separated representatives of the dicotyledons:

“Systematists segregate angiosperms into two series—monocotyledons and dicotyledons—and there has been almost endless discussion as to which line was the more primitive. Both were present in the Cretaceous period, so that history fails to shed any light on the problem. Formerly, gymnosperms and other remains from the older rocks were thought to represent monocotyledons, but none such are now recognized. Modern opinion tends in the direction of regarding the distinctions between these two groups as largely cumulative, and that the number of the cotyledons and the correlative characters are of less phylogenetic importance than was formerly believed. The view is here advocated that the angiosperms are strictly monophyletic, that the monocotyledons are not primitive, nor did the primitive angiosperms exhibit combined monocoty-

¹ See BANCROFT, N. A review of literature concerning the evolution of monocotyledons. *The New Phytologist*, XIII: 9, 1914.

ledonous and dicotyledonous characters, but that the dicotyledonous type is the more primitive, and that it has given rise to the monocotyledonous stock, not, however, as a single or monophyletic line of evolution, but by one such line combined with several reduction series derived from different regions in the dicotyledonous plexus. Systematists have long recognized the similarities between the monocotyledonous arums, pond weeds, and screw pines on the one hand, and the dicotyledonous peppers and willows on the other, as well as the convergence of certain Ranalian groups and the water plantains. The case of the water lily family is a classic instance of a group of dicotyledonous origin which has essentially reached the monocotyledonous category."¹

Such an origin, if true, involves a remarkable series of parallel changes in three major characters: number of cotyledons, leaf venation, and arrangement of vascular bundles in the stems. No one of these changes, by itself, seems at all impossible. Formerly it was assumed, from incomplete investigation, that in monocotyledons the terminal cell of the embryo formed the cotyledon and a lateral cell below it formed the tip of the stem, while in dicotyledons the stem was terminal and the cotyledons lateral—a rather fundamental distinction, not easy to change. If this distinction was ignored it was easy to maintain, on morphological evidence found in different species, that monocotyledony arose either (1) by a fusion of two cotyledons in their formation, or (2) by a partial or total suppression of one of the cotyledons. The “epiblast,” found in many grasses, has long been recognized as an undeveloped cotyledon. The problem has been simplified by Coulter² and his associates, who have shown that the origin of the embryonic stem in monocotyledons is not lateral but terminal, and that cotyledons originate, not from a terminal cell but from a “peripheral cotyledonary zone” which may develop one, two, or several cotyledons, or in a few species none at all. In angiosperms two generally start, but if growth continues in only one, the embryo is monocotyledonous.

With regard to other characters, attention has already been called to the fact that not all monocotyledons and dicotyledons are typical of their groups in all respects. The atypical struc-

¹ BERRY, E. W., Paleobotany, *Ann. Rept. Smithsonian Institution*, p. 369, 1918.

² COULTER, J. M. The origin of monocotyledony. *Ann. Mo. Bot. Gard.*, 2: pp. 175–183, 1915.

tures are not, however, characteristic of large groups of monocotyledons or dicotyledons, but are quite scattered. Examples are the netted veined leaves of *Smilax rotundifolia* L. and *Arisaema triphyllum* (L.) Schott., and the somewhat scattered vascular bundles in the stem of *Thalictrum* and *Nymphaea*.

Description.—The monocotyledons are mostly herbaceous plants but some (e.g., palms) are large trees. With rare exceptions the leaves have unbranched parallel veins running either longitudinally or from the midrib outward. The embryo has one cotyledon that remains below ground with the endosperm during germination. A second may be present in more or less rudimentary condition. The stem is not divided into bark, wood, and pith, but the vascular bundles, collateral in type, are scattered throughout a soft pith-like parenchyma. The floral parts are usually in threes or multiples of three, i.e., 3-merous. The calyx in many species is colored and corolla-like.

52. GRAMINEAE (POACEAE). Grass Family

The Gramineae constitute the second largest family of monocotyledons, containing about 500 genera and 4,500 species. Of the species found in America more than three-fourths are native. The grasses are the most universally distributed, and the most numerous in individuals, of any family of spermatophytes. The great adaptability of the different species has enabled them to thrive under the most varied conditions: in standing water and in deserts, on sun-baked hillsides and in all but the most densely shaded forests, in sand and in gumbo clay, far above the timber line on lofty mountains, and well into the arctic regions.

Fossil remains of grasses have been found in rocks of the Lower Cretaceous period, but in all probability the great diversity of form now found within the family is a relatively recent development. Their simplicity is due to degeneration or specialization rather than to primitiveness. It is probable that the order Graminales should be looked upon as a specialized side branch of the main genetic line of monocotyledons, and as one that has given rise to no other orders.

Familiar Examples.—The well-known members of the Gramineae are too numerous to mention. Representative examples are wheat (*Triticum aestivum* L.), corn (*Zea Mays* L.), oats (*Avena sativa* L.), rice (*Oryza sativa* L.), sorghum (*Holcus Sorghum* L.), sugar cane (*Saccharum officinarum* L.), bamboo (*Bambusa* spp.),

timothy (*Phleum pratense* L.), and Kentucky blue grass (*Poa pratensis* L.).

Stems and Roots.—The grasses are nearly all herbaceous. The prevailing type of stem is a cylindrical culm with conspicuous nodes and hollow internodes, although solid stems are not unusual among the larger members such as corn, sorghum, and sugar cane. Annual, biennial, and perennial species are all numerous. The largest woody species are the bamboos, which may grow to more than 100 feet in height and several inches in diameter. Among the perennial grasses there is a marked tendency to the formation of rhizomes, underground rootstocks that in some species, such as quack grass, extend for a considerable distance and serve the function of vegetative propagation. The roots are usually fibrous and fasciated. Small tubers or corms are found in a few species.

Leaves.—Almost without exception the blade (lamina) of the leaf is narrow and ribbon-shaped. The arrangement on the stem is alternate and two-ranked. The leaf is attached to the node by a long sheath, which clasps the stem. This sheath in most species is split throughout its length on the side opposite the attachment of the blade. The union of blade and sheath is usually not a smooth one. Often it appears as if the blade attached slightly below the top of the sheath, and this apparent projection of the sheath above the attachment is called a ligule. It is thinner and more membranous than the sheath proper and is sometimes fringed. The base of the blade at its two margins often projects to form two small ear-like portions called auricles.

Inflorescences and Flowers.—The inflorescences are composed of several to many spikelets, which are combined in various ways on a main axis called the rachis. Some are in compound spikes, as wheat, others are in racemes, as certain species of *Festuca* and *Paspalum*, while still others are in panicles, as oats. It should be understood, however, that the panicles of *Avena*, *Panicum*, etc., are not quite comparable with the panicles of *Yucca*, *Heuchera*, and *Thalictrum*, for example, as in the former each slender stalk bears a spikelet of flowers while in the latter it bears a single flower.

As the spikelet is the unit of structure in the inflorescence its morphology merits special attention. Through the center of the spikelet runs a tiny stalk or axis, the rachilla, to which the other parts are attached. In a typical spikelet, as found in wheat,

these parts are as follows: at the base of the spikelet is a pair of scales, called glumes, enclosing the portions above; just above the second glume is a similar scale, the lemma, which, in many species, has a long, slender, pointed awn usually growing from its tip; in the axis of this lemma the flower is formed. The outer perianth of the flower is a two-keeled scale, the palet, and the stamens and pistil lie between the lemma (on the outer side) and the palet (on the inner side, *i.e.*, toward the rachis). The inner perianth consists of two tiny scale-like lodicules set between the

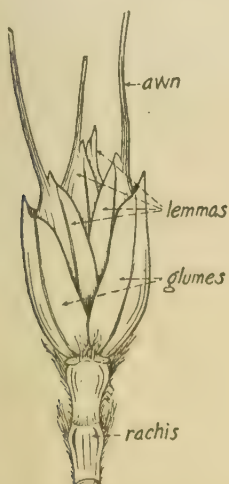


FIG. 55.—*Triticum aestivum* (Gramineae). Single spikelet. (After Robbins.)

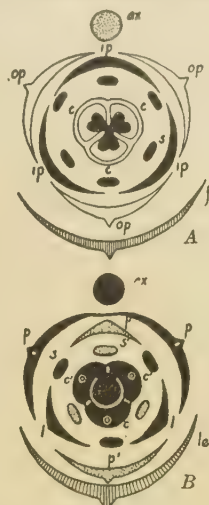


FIG. 56.—A, floral diagram of lily flower (Liliaceae) for comparison with B, floral diagram of grass flower (Gramineae). Shaded structures have been suppressed in the evolution of the flower. (A, after Robbins; B, after Schuster.)

lemma and the ovary. The stamens are three in number (rarely one, two, or six), the filament attaching to the sagittate base of the anther. There is a single pistil with a superior ovary and two feathery stigmatic styles. Farther up on the spikelet are other similar flowers, the upper ones often sterile.

Flower study in the grasses is complicated by the fact that there has been much suppression and modification of floral parts, and this has taken place in varying degrees in different species. The perianth condition of the grass ancestor is unknown, but it is not unlikely that it consisted of two whorls of three

parts each. Three lodicules can still be found in some species. There probably were six stamens, this number still being found in bamboo and in rice. The pistil doubtless had three carpels; in fact, studies in the early development of the flowers have shown that this number still persists, although they are so intimately fused that they appear as one. Three styles, suggestive of as many carpels, are not unusual. In most species the flowers are bisexual, but in corn, for example, the stamens and pistils are

in separate flowers. Even here bisexual flowers in the staminate tassels are fairly common. This specialized floral structure furnishes ground for the belief that the grasses are not primitive plants but derivatives of lily-like ancestors.



FIG. 57.—*Bambusa* (Gramineae). Floral diagram. (After Ward.)

Fruits and Seeds.—The one-ovulate pistil develops into a hard, dry, seed-like fruit, similar to an achene, but strictly speaking a caryopsis, as the seed adheres closely to the surrounding ovary wall. In some species, such as oats and hulled barley, the palea and lemma continue to enclose the grain after threshing. The seed is composed largely of starchy endosperm with a relatively small straight embryo near the point of attachment.

Economic Significance.—Undoubtedly the Gramineae excel all other families in their importance to mankind. Without Pinaceae we might live in earthen houses; without cotton we might clothe ourselves in other fabrics; but without Gramineae most of us would starve. Notwithstanding the prevalence of hundreds of other families of plants the earth would support far less animal life were it not for the grasses and grains.

The explanation is not difficult. In the first place the grasses are abundant; they grow everywhere, under all conditions, filling in the spaces between larger plants and crowding out those that are poorer competitors. In the second place they withstand injury unusually well, rallying promptly when cut or eaten off. How many other species can withstand steady pasturing by livestock, or the daily use of the lawn mower? Then, too, they are palatable and nutritious, and practically none are poisonous. The Gramineae furnish summer forage, winter hay, grain for livestock, and bread for man.

Of the different grains, wheat and rice are outstandingly the most important, considering the entire human race, with corn, oats, barley, and rye trailing after.

From the food standpoint we must not overlook sugar cane, which, with sorghum, furnishes the bulk of the world's sugar.

Aside from the food supply the Gramineae have some importance. We in America can hardly appreciate the extent to which bamboo is used in certain parts of the world where timber is scarce. Its great size, strength, and lightness adapt it well for bridges, buildings, furniture, and implements, while much of the waste is used for fuel.

Not even the stately pines nor the showy flowers contribute more to the adornment of the earth than do the beautiful carpets of grass that hide her nakedness.

In so large a family it is not surprising that man should find some undesirable members. None are distinctly poisonous, but a few protect themselves by sharp saw-teeth on the margins of the leaves and by spines. As would be expected among plants so adapted to competition with other forms of life many pernicious weeds may be found. Notable among these are cheat or chess (*Bromus secalinus* L.), downy brome grass or military grass (*B. tectorum* L.), quack grass or couch grass (*Agropyron repens* (L.) Beauv.), wild oat (*Avena fatua* L.), green foxtail (*Setaria viridis* (L.) Beauv.), and squirrel tail or wild barley (*Hordeum jubatum* L.).

53. CYPERACEAE. Sedge Family

The sedges, often called "slough grasses," resemble the true grasses so much that they are commonly mistaken for them. There are about 75 genera and 3,200 species, widely distributed over all parts of the world, but especially abundant in wet soils. Only about ten per cent of the species are found in the United States. The sedges are distinguished from the grasses by the following characters, to some of which there are occasional exceptions: (1) angular stems without joints, (2) three-ranked leaves, (3) closed leaf sheaths, (4) only one glume at the base of each flower, (5) perianth composed of bristles or lacking, and (6) seed free from wall of fruit (achene).

Familiar Examples.—Slough grass (*Carex* spp.), bulrushes (*Scirpus* spp.), and umbrella plant (*Cyperus alternifolius* L.) are the commonest examples.

Stems and Roots.—The Cyperaceae are practically all herbaceous, annuals or perennials, rarely biennials. The stems are usually solid and without nodes between inflorescence and crown. In the majority of species they are triangular but in some they are quadrangular, flattened, or cylindrical. The roots are fibrous and fascicled, many of them on perennial species being adventitious from underground rootstocks.

Leaves.—The leaves are mostly linear and grass-like, but the leaf sheath in nearly all species is closed. They have a three-ranked arrangement on the stem. The ligules are absent or very much reduced.

Inflorescences and Flowers.—As in the Gramineae, the spikelet is the unit of structure in the inflorescence. The flower structure differs chiefly in the further reduction of the perianth to a few bristles and even these may be absent. The flowers have a single glume at the base instead of two as in the Gramineae. They may be bisexual or unisexual. There are typically three stamens but sometimes more or fewer. The carpels are united in the pistil, which has two or three styles or style branches.

Fruits and Seeds.—The fruit is an achene, usually three angled, containing one seed. This is free from the ovary wall and has a very small embryo and a large soft endosperm.

Economic Significance.—Compared with the Gramineae the Cyperaceae are of limited importance. The grains as a rule are small, few in number, and insignificant. While a few species make good pasturage and hay, most of them do not. Generally they are too succulent in the spring and too hard and wiry in the fall. This harsh texture is due in part to serrations on the leaves and in part to deposits of silicates in the leaves and stems.

The papyrus, early used for paper making, belongs to this family, but it has been largely superseded by straw, linen, and wood pulp.

None of the Cyperaceae are poisonous and they are unimportant as weeds except where swampy land is cultivated.

54. ARACEAE. Arum Family

The family Araceae contains about 100 genera and 1,500 species, most of which are subtropical or tropical. They tend to be aquatic but some are epiphytic.

Familiar Examples.—The common calla or calla lily of greenhouses (*Zantedeschia aethiopica* Spreng.), Jack-in-the-pulpit or

Indian turnip (*Arisaema triphyllum* (L.) Schott.), sweet flag (*Acorus calamus* L.), and skunk cabbage (*Symplocarpus foetidus* (L.) Nutt.) are familiar examples.

Leaves.—The leaves are mostly large, simple or compound, usually parallel veined, but netted in some species as *Arisaema triphyllum*. In the western skunk cabbage (*Lysichiton camtschatensis* (L.) Schött.), they are of enormous size—more than 3

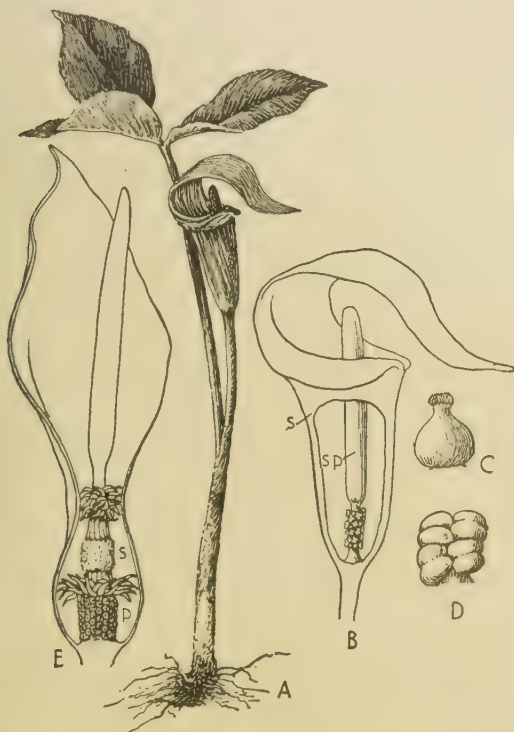


FIG. 58.—*Arisaema triphyllum* and *Arum* (Araceae). A, entire plant. B, spadix with portion of spathe cut away. C, pistillate flower. D, staminate flower. E, inflorescence. S, staminate flowers. P, pistillate flowers. (After Curtis.)

feet long and half as wide. In *Monstera deliciosa* Liebm. of the tropics, sometimes grown in greenhouses, the huge leaf blades are perforated with many natural openings, 1 to 3 inches long by $\frac{1}{2}$ to 1 inch wide.

Stems and Roots.—The Araceae are herbaceous, or the larger forms slightly woody. Some are vine-like and climb by aerial

roots. Epiphytic forms are occasionally found in the tropics. Underground stems are usually developed in the form of rootstocks, tubers, or corms, which often have a very pungent taste.

Inflorescences and Flowers.—The striking feature of the Araceae is the inflorescence. This consists of a spadix subtended by a spathe. This entire structure is sometimes of astonishing appearance, being nearly 3 feet long in devil's tongue (*Amorphophallus rivieri* Dur.) and colored deep red. In calla lily and most other members of the family the inflorescence commonly passes for a flower. The true flowers are unisexual or rarely bisexual. Generally the staminate flowers are at the top of the spadix and the pistillate below, but some species are dioecious. The perianth is reduced to tiny scales or ridges or is entirely lacking. There are commonly ten stamens or fewer. The single pistil has one to several carpels.

Fruits and Seeds.—The fruit is a berry or utricle. In some species the seeds contain endosperm; in others there is none.

Economic Significance.—General interest in this family is centered in the beauty or oddity of the inflorescence. The corms or tubers are edible in a few species, but they are generally too acrid to be palatable. A few of the members are reputed to be poisonous. The calamus of the drug trade is obtained from the rootstocks of *Acorus Calamus*.

55. JUNCACEAE. Rush Family

The rush family consists of 2 genera and about 300 species of herbaceous, aquatic, often grass-like or sedge-like plants. In reality they are more nearly related to the lilies than to the grasses and sedges, and they are included in the order Liliales.

Familiar Examples.—Familiar examples are common or bog rush (*Juncus effusus* L.) and wood rush (*Luzula parviflora* (Ehr.) Desv.) but not bulrushes, which belong to the Cyperaceae.

Stems and Roots.—The Juncaceae are all herbaceous and mostly perennial, growing in dense bunches often 1 to 3 feet high. The stems may be cylindrical or angled and contain a soft pith. The roots are fibrous.

Leaves.—The leaves are linear but variable as to thickness. In the larger genus, *Juncus*, the sheaths are split. In the other, *Juncoides*, they are closed.

Inflorescences and Flowers.—Unlike the grasses and sedges, the inflorescences are not made up of spikelets but of single

flowers arranged in different ways —racemes, panicles, corymbs, heads, or false umbels.

The flowers in most species resemble in structure a reduced lily. There are three sepals and three petals of similar, broad, greenish-brown scales. The stamens are typically six in number, but in some species have been reduced to three, four, or five. The pistil has three distinct carpels and usually three cavities. The general effect of the inflorescence is that of a sedge, olive-green or brownish in color; but close inspection shows a flower structure more like the lilies.

Fruits and Seeds.—The fruit is a tiny capsule containing three seed chambers, or by the omission of partitions only one. Several seeds are produced in each chamber. The embryo is small and straight in a fleshy endosperm.

Economic Significance.—Economically the Juncaceae are of little importance. Most species are wholly ignored by livestock, but a few, notably the wood rush, which grows in non-swampy land, are relished.



FIG. 59.—*Juncus lamprocarpus* (Juncaceae). *a*, inflorescence. *b*, single flower. *c*, pistil. (After Strasburger.)

56. MELANTHACEAE. Bunch-flower Family

The family Melanthaceae includes about 40 genera and 145 species. It belongs to the order Liliales, and its members are, by some authorities, included in the family Liliaceae. It is distinguished from the Liliaceae as here given by the septicidal dehiscence of its capsules and its absence of bulbs.

Familiar Examples.—Bunch-flower (*Melanthium* spp.), bear-grass or turkey beard (*Xerophyllum* spp.), and death-camas (*Zygadenus venenosus* S. Wats.) are well-known examples.

Stems and Roots.—Most stems and roots of this family are perennial herbs with fleshy rootstocks. In the genus *Zygadenus* bulbs are produced.

Leaves.—The leaves are narrow in most species and alternate on the stem.

Inflorescences and Flowers. The inflorescences are usually racemes or panicles with numerous symmetrical flowers. The



FIG. 60.—*Zygadenus venenosus* S. Wats. (Melanthaceae.) Death camas. At least four species of *Zygadenus* found from Montana westward and southward are known to be poisonous from the presence of the alkaloid zygadenine. (One-half natural size.)

three sepals are often petal-like. There are three petals, usually white, pale green, or pale yellow, the entire inflorescence often being large and showy. There are six stamens and a tricarpellate pistil with three chambers and three styles. In some species the flowers are bisexual, in others unisexual and even dioecious.

Fruits and Seeds.—The fruit is a three-chambered capsule, several to many seeded. The dehiscence is septicidal, *i.e.*, through the partitions, in which respect it differs from that of the Liliaceae. The seeds usually bear appendages. The embryo is small in abundant endosperm.

Economic Significance.—The Melanthaceae are of small economic importance. A few species are ornamental. Death Camas (*Zygadenus venenosus* S. Wats.) causes some losses among sheep and occasionally among other livestock, and has been eaten by human beings with fatal results. The family is discussed here because of its close relationship with Liliaceae, with which it is included by some authorities.

57. LILIACEAE. Lily Family

The lilies and their relatives constitute a large family of splendid ornamental plants. There are about 125 genera and 1,300 species distributed all over the world. Some botanists include the Melanthaceae and the Convallariaceae with this family. The grounds for making separate families of them are, perhaps, rather scanty, but where all three are combined the family is quite unwieldy and few statements can be made that will apply to all species. Generally the Melanthaceae are distinguished from the Liliaceae by the septicidal dehiscence of their capsules and by the absence of bulbs. The Convallariaceae are distinguished from the Liliaceae by their fleshy berries in place of capsules.

Familiar Examples.—Examples are the true lily (*Lilium* spp.), but not the calla lily (*Zantedeschia aethiopica* Spreng.), adder's tongue or dog-tooth violet (*Erythronium* spp.), tulip (*Tulipa* spp.), Spanish bayonet (*Yucca* spp.), and onion (*Allium* spp.).

Stems and Roots.—The Liliaceae are nearly all perennial or biennial herbs, but a few shrubby species (*Dracaena* spp.) are found in the tropics. The conspicuous underground portion is a bulb or a corm, rarely a fleshy rootstock. Many fibrous roots grow from these fleshy portions. In some cases the bulbs or

corms serve merely to store food for seed production the following year. In others they form in considerable numbers and serve for vegetative propagation.

Leaves.—The leaves of Liliaceae are all simple and parallel veined, but otherwise somewhat variable. In shape they grade

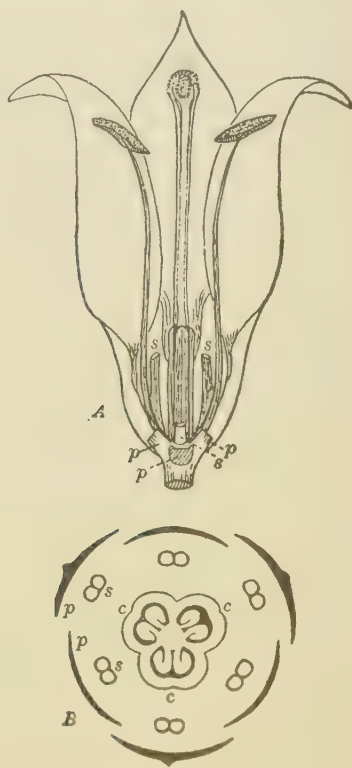


FIG. 61.—*Lilium philadelphicum* (Liliaceae). A, longitudinal section of flower. B, floral diagram. (After Bergen and Davis.)

from linear to broadly ovate. In some species they are all basal. In others they are alternate, opposite, or whorled.

Inflorescences and Flowers.—Various forms of inflorescence are found—racemes, panicles, and umbels—and not a few species have solitary flowers. The flowers are bisexual and usually have three petal-like sepals, three large equal petals, six stamens, and a tricarpellate pistil with a superior ovary, three seed chambers, and one style with a three-lobed stigma.

Fruits and Seeds.—The fruit is a three-chambered capsule with loculicidal dehiscence, *i.e.*, directly into the seed cavities (except in *Calochortus*). The number of seeds varies from few to many. They contain a small embryo within a large endosperm.

Economic Significance.—From the esthetic standpoint few families of plants compare with the Liliaceae. The great abundance, variety, and size of the flowers give them much prominence in the greenhouse, flower garden, dooryard, and field. The fact that many of them can be so easily grown from bulbs or corms brings them into the humblest homes and the stateliest mansions. Their food value for human use is limited to a few bulbs—onions, camas, etc.—and their forage value is practically nil. They are not troublesome as poisonous plants or as weeds.

58. CONVALLARIACEAE. Lily-of-the-Valley Family

About 23 genera and 215 species much like the Liliaceae, with which they are often included, constitute this family. It differs from the Liliaceae in the character of the fruit, which here is a fleshy berry.

Familiar Examples.—Lily-of-the-valley (*Convallaria majalis* L.), false Solomon's seal (*Smilacina* spp.), and asparagus (*Asparagus officinalis* L.) are familiar examples.

Stems and Roots.—Mostly perennial herbs with fleshy rootstocks, but never bulbs or corms. The roots are fibrous, mostly from the rootstocks.

Leaves.—The leaves are extremely variable. In addition to the kinds usually found in this part of the plant kingdom, *Asparagus* has scale-like leaves, and some species of *Uvularia* have perfoliate leaves, *i.e.*, the stem appearing to run through the leaf blade.

Inflorescences and Flowers.—The flowers may be solitary or borne in racemes, panicles, or umbels. They are bisexual, with three sepals, which are often petal-like, and three rather small equal petals. The sepals and petals of the perianth are often almost indistinguishable and in *Polygonatum* they are united into a six-toothed tube. In *Maianthemum* there are only four segments. There are six stamens (rarely four), generally hypogynous, but in some species attached to the united perianth. The ovary is superior, tricarpellate, and one to three chambered.

Fruits and Seeds.—The fruit is a berry or rarely a capsule, with few to many seeds. They have small embryos and abundant endosperm.

Economic Significance.—Lily-of-the-valley and others are much treasured flowers, and asparagus is extensively grown as a vegetable.

59. IRIDACEAE. Iris Family

About 57 genera and 1,000 species widely distributed in temperate and warmer regions, becoming fewer northward, constitute this family. That they are among the highest members of the Liliales is shown by their inferior ovaries and reduced stamen number, and by the united filaments in *Sisyrinchium*.

Familiar Examples.—The best-known examples are the different kinds of iris, flag, or fleur-de-lis (*Iris* spp.), both wild and cultivated, gladioli (*Gladiolus* spp.), and the blue-eyed grasses (*Sisyrinchium* spp.).

Stems and Roots.—The Iridaceae are all perennial herbs, and most of them have fleshy underground rootstocks, corms, or bulbs.

Leaves.—The leaves are mostly lanceolate or linear, two-ranked, with clasping bases.

Inflorescences and Flowers.—The flowers are mostly large and showy, single or few in a cluster, and subtended by bracts. They are bisexual and usually regular. The perianth is composed of three petal-like sepals and three petals, forming a tube adherent to the ovary. The three stamens are attached to this tube opposite the sepals. The pistil is tricarpellate, with an inferior ovary divided into three chambers. The styles have three branches which are sometimes expanded and petal-like, as in *Iris*, where they add much to the appearance of the flower.

Fruits and Seeds.—The seeds are numerous in a dehiscent capsule. The endosperm is abundant and the embryo is small and straight.

Economic Significance.—Some of the finest of our flowers belong to the Iridaceae. They are also interesting in showing the progress of evolution in the monocotyledons, culminating in the Orchidaceae.

60. ORCHIDACEAE. Orchid Family

The monocotyledons reach the climax of their development in the Orchidaceae. This is the largest family of the monocotyledons and the second largest of all the angiosperms, being exceeded only by the Compositae. Indeed it is not unlikely that when the tropics have been thoroughly explored the number of orchid

species will be placed first among the flowering plants. There are at least 500 genera and 9,000 species, mostly tropical or subtropical but a few growing as far north as Canada. In floral complexity they surpass everything else in the plant kingdom, the specialization being largely to facilitate insect pollination. It is indeed debatable whether or not we are justified in calling the Compositae, the highest of the dicotyledons, more advanced than the Orchidaceae, the highest of the monocotyledons. The Compositae show the greatest advancement in inflorescence, but the Orchidaceae show the greatest advancement in floral structure, although, as has been pointed out by Bessey, much of the specialization in the Orchidaceae is in the petals, which are the most easily modified of all the floral organs.

Familiar Examples.—Many well-known flowers belong to this family—greenhouse orchids (*Cattleya* spp.), lady's slipper (*Cypripedium* spp.), and coral-root (*Corallorrhiza* spp.).

Stems and Roots.—The Orchidaceae are perennial herbs, mostly terrestrial and green, but a considerable number epiphytic with aerial roots, and a few chlorophyllless and either saprophytic, or parasitic on the roots of other plants. The stems are usually erect but sometimes trailing or climbing. Most species produce fleshy roots, rootstocks, corms, or bulbs.

Leaves.—In most terrestrial and epiphytic species the leaves are fairly uniform excepting as to width, in which respect they vary from linear to broadly ovate. In saprophytic and parasitic species (*Cephalanthera* and *Corallorrhiza*), they are reduced to scales. Characteristically the leaf bases are sheathing on the stem. In arrangement they are usually alternate, but sometimes opposite and occasionally whorled.

Inflorescences and Flowers.—In many species the flowers are solitary but more often they are in racemes or spikes. The flowers are the most remarkable feature of the Orchidaceae. They present so great a variety of detail that only the general plan can be given here. They are bisexual and irregular, *i.e.*, bilaterally symmetrical. There are three sepals, either green or colored to match the corolla, and like each other in appearance. Two of the three petals are alike or right and left mates, and are called "wings." The third, below the other two, is unlike the wings, often very much so, being bulbous, spurred, tubular, strap-shaped, or variously branched, and contributing most to the beauty and oddity of the flower. This highly specialized petal

is called the "lip." The most characteristic part of the flower is the gynandrium or "column" which is made by a fusion of the three stamens with the pistil. Only one or two of the stamens are functional, and these usually produce two or more stalked pollen masses, pollinia, which are often waxy or even viscid. One lobe of the stigma often extends to form a beak—the rostellum. The other two on either side are viscid and functional. These parts of the gynandrium are variously proportioned in



FIG. 62.—*Cypripedium hirsutum* (Orchidaceae). Showing the highly specialized corolla. (After Sinnott.)

different species, and with the variable lip give endless floral combinations. The pistil is tricarpellate, with an inferior ovary containing one cavity with many ovules.

Fruits and Seeds.—The fruit is quite regularly a three-valved capsule containing many seeds, which are very tiny, with an undifferentiated embryo and no endosperm.

Economic Significance.—The flowers of the Orchidaceae are the most cherished of any in the plant kingdom. Their culture in the greenhouse has become a fine art. In the tropics their remarkable colors, form, and profusion are a constant delight to the traveler. Even in temperate zones the lady's slippers and a few others make an important contribution to the flora.

Unfortunately the Orchidaceae are sensitive to abuse, and picking the flowers soon exterminates the plants. There are too many people so constituted that their impulsiveness far exceeds their judgment. They cannot seem to learn the relative value of flowers that are growing and those that are picked and wilting. In many sections where lady's slippers were once abundant they can no longer be found, or have become so rare that they are hunted the harder.

COMPARISON OF ORCHIDACEAE AND COMPOSITAE

As the Orchidaceae and Compositae are generally considered the highest types of the monocotyledons and the dicotyledons respectively, some useful lessons may be learned by a comparison of the two families:

	Orchidaceae	Compositae
Habit.....	*Mostly herbaceous perennials. Many epiphytic and a few saprophytic or parasitic. Often vine-like	Mostly herbaceous annuals. All autophytic and terrestrial. Practically always erect
Stems.....	*With scattered vascular bundles	With vascular bundles arranged in a hollow cylinder
Leaves.....	*With parallel venation. All simple	With netted venation. Mostly simple
Inflorescences.....	Mostly racemes or spikes, but many solitary flowers	*Heads, some of great size
Floral size.....	*Generally large and showy	Relatively very small
Floral parts.....	Trimerous; stamens reduced	*Pentamerous; carpels reduced
Insertion.....	Epigynous	Epigynous
Floral shape.....	*All irregular—some extremely so	Mostly regular; rays irregular
Calyx.....	Well developed and often colored	*Much reduced or wanting
Corolla.....	Polypetalous	*Gamopetalous
Sexuality.....	Bisexual	*Bisexual, unisexual or neutral

* A star is here used to indicate that the condition is less primitive in this family than in the other. In some cases there may be a difference of opinion as to which is the more primitive, especially where regressive development has taken place.

	Orchidaceae	Compositae
Androeceum	*Originally of six stamens now reduced to three, of which one or two are stam-inodes. United to the pistil. Produce pollinia	Usually five stamens which are connate. Produce powdery pollen.
Gynoeceum	*Tricarpellate, one-cham-bered. Often greatly modified	Bicarpellate, one-cham-bered
Pollination	*Entomophylous	Anemophylous or entomo- phylous
Placentation	Parietal	*Basal
Ovules	Numerous. Anatropous	*Single. Anatropous
Fruit	Capsule	*Achene
Seeds	Without appendages	Without appendages
Endosperm	None	None
Embryo	*Undifferentiated (through reduction)	Straight. Dicotyledonous

* A star is here used to indicate that the condition is less primitive in this family than in the other. In some cases there may be a difference of opinion as to which is the more primitive, especially where regressive development has taken place.

From the foregoing table it may be seen that even the most highly developed plants may be primitive with regard to certain structures. Indeed, more than half of the primitive characters of the angiosperms are illustrated in one or both of these "highest" families.

The relative number of stars in the two columns does not furnish a safe criterion of the relative advancement of the two families, for the characters are not necessarily of equal importance. The student will, however, find it profitable to make similar comparative tables of other families, especially as relationships between families may often be brought out by such comparisons.

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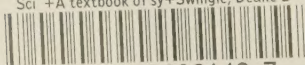
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